

Calculations of Painting Wasteloads
Associated with Metal Finishing

Coating Consultants
Brighton, MI

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CALCULATIONS OF PAINTING WASTELOADS
ASSOCIATED WITH METAL FINISHING

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FOREWORD

When energy and material resources are extracted, processed, converted, and used, the related pollutional impacts on our environment and even on our health often require that new and increasingly more efficient pollution control methods be used. The Industrial Environmental Research Laboratory-Cincinnati (IERL-Ci) assists in developing and demonstrating new and improved methodologies that will meet these needs both efficiently and economically.

The subject of the present study is the tabulation of the relative sizes of the waste loads generated by commonly used industrial paints and painting processes. A system of mathematical equations has been developed for the computation of the waste loads expected for any size and for almost any kind of industrial painting operation. All parties concerned with the selection of less wasteful methods of industrial painting will find this report to be a ready tool for their work. For further information regarding this study the Industrial Pollution Control Division should be contacted.

David G. Stephan
Director
Industrial Environmental Research Laboratory
Cincinnati

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ABSTRACT

This study presents methods for predicting the waste loads that will be generated in planned painting operations, and for determination of the actual waste loads in current operations.

Nine major classes of industrial paints and the most widely used industrial painting processes were surveyed and have been described. The upper and lower limits of frequently encountered waste loads have been tabulated.

Twelve mathematical equations have been developed for the prediction of waste loads or for determination of actual waste loads.

This study indicated that the waste loads generated in most painting operations can be significantly reduced through the use of better paint materials and more efficient painting processes. Such technologies are currently in various stages of development, but their wide-spread adoption will require years of field testing so that environmental demands and consumer quality expectations can be fully assured.

This report is submitted in fulfillment of Grant No. R 803467 by Coating Consultants, Brighton, Michigan under the sponsorship of the U. S. Environmental Protection Agency.

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ABBREVIATIONS AND SYMBOLS

A	-- area	W _{det}	-- determined waste
A _h	-- hanger area	W _{et}	-- predicted waste at the expected transfer effi- ciency
A _m	-- merchandise area	wNV _{cons}	-- weight of NV consumed
A _{max}	-- maximum area		
A _p	-- area painted		
COR	-- coreactants		
d	-- density		
dNV	-- density of nonvolatiles		
dOV	-- density of organic volatiles		
exp.t.e.	-- expected transfer efficiency		
K	-- constant		
NV	-- nonvolatiles		
OV	-- organic volatiles		
T	-- total		
t	-- thickness		
t _h	-- thickness on hangers		
t _m	-- thickness on merchandise		
v	-- volume		
w	-- weight		
wt%	-- weight percent		
W	-- waste		

CONVERSION FACTORS

From: Metric	To: U. S.	Multiply by
cm	in	0.3937
cm ²	in ²	0.155
cm ³	in ³	0.061
kg	lb	2.203
kg/l	lb/gal	8.338
l	gal	0.264
m	ft	3.281
m ²	ft ²	10.753
μm	mil	0.0394

From: U. S.	To: Metric	Multiply by
ft	m	0.3048
ft ²	m ²	0.093
gal	l	3.785
in	cm	2.54
in ²	cm ²	6.452
in ³	cm ³	16.393
lb	kg	0.454
lb/gal	kg/l	0.12
mil	μm	25.4

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SECTION 1

INTRODUCTION

GENERAL

Large quantities of contaminants are emitted into the environment as a result of painting operations in the metal fabricating and finishing industries.

Prior to 1960, typical industrial paint formulations contained approximately 40 wt% of paint solids dispersed in volatile organic solvents. Thus, 60% of the total weight of all paints sold in the United States resulted in organic volatile waste. In addition, an estimated 20% of the total paint solids weight became waste due to overspray, drip-off, and spillage.

Painting operations result in the generation of three classes of contaminant wastes:

- 1) Vapors of organic volatile solvents which are emitted into the atmosphere unless they are captured and incinerated. (Incineration may cause secondary pollutional waste loads which were not considered in this study.)
- 2) Solid or semisolid nonorganic materials (resins or pigments) combined with some adhering organic volatile solvents which must be buried in the ground, either directly or after partial incineration. (In certain cases, some paint solids waste may be economically reclaimed.)
- 3) Minor quantities of nonvolatile waste (water soluble solvents, salts, surfactants, and other additives) which may find their way into clearing lagoons, sewers, or waterways.

Since 1960, an increased awareness of environmental factors has resulted in replacement of many particularly detrimental liquid paint components with less objectionable materials. Numerous new ecologically desirable improvements in paint technology have been reported; in particular there have been waterborne paints, high solids paints, paint powders, and radiation cured paints introduced on the market.

In 1970, it was estimated that the annual waste load generated by industrial painting operations was more than 200 million kilograms (220 thousand tons) of organic volatile waste plus an additional 100 million kilograms

(110 thousand tons) of semisolid waste that contained some organic volatiles.¹ At that time, approximately 60% of all industrial painting was done by conventional spraying processes. By use of this method, 40 to 60% of the paint solids which enter the plant are not transferred onto the merchandise, but are lost as unavoidable overspray. Paint transfer methods other than conventional air atomized spraying were variously reported as operating with much higher transfer efficiencies, some as high as 98%.

In 1973, inquiries which were addressed to the two largest organizations in the field --the Federation of Societies for Paint Technology, Philadelphia, Pa., and the National Paint and Coatings Association, Washington, D.C.-- did not produce any comprehensive surveys or statistics. At that time, no tabulations existed as to the quantities of waste generated by various types of paints or by the use of different painting processes.

A literature search produced a number of articles dealing with narrow facets of the problem of painting wastes, but the literature did not reveal a generally accepted method that would allow the determination of the waste load generated by any given industrial painting operation. No method was found in the literature for the mathematical prediction of the waste load that would be generated by a given size and kind of painting operation. The literature did not contain a method to predict the change in waste load that would result from replacing one kind of paint or painting process with another.

SCOPE

This study presents data which allows the calculation of predicted waste loads generated during the application of widely used paints by various common painting processes. The reported data were compiled from the reviewed scientific and trade literature and through direct communications with experts in the painting field.

Liquid or vaporized wastes and semisolid wastes are reported in weight and volume units for a specific size of painting operation and allow, therefore, the computation of the waste load for any size of painting operation.

PURPOSE

This study is intended to be a useful tool for the prediction of waste loads that will be generated by an industrial painting operation when a given quantity of merchandise is to be painted using common paints and painting techniques.

This study can also be used for the determination of the actual waste loads generated by a specific industrial painting operation and for pinpointing unnecessary costly and polluttional losses. It should also be an aid to those engaged in the selection of the best available paint and painting process for a particular job.

¹ Wapora, Inc.: EPA Contract No. 68-01-2656

THEORETICAL APPROACH

Premises

- 1) Paint formulations are varied somewhat from user to user and batch to batch to adjust to changes in the market, color, processing equipment, etc.
- 2) Paints are invoiced either by weight or by volume.
- 3) The user buys most paints in liquid form, but actually uses only the paint solids on the finished product. The total volume of the organic volatiles in the liquid constitutes a waste load.
- 4) Loss of some portion of the paint solids is inherent in all painting processes. Accidental losses will also occur and contribute additional organic volatiles plus nonvolatile paint solids to the waste loads.
- 5) Industrial painting operations vary in size, and production output fluctuates with the market.

Method

In consideration of the above premises, the waste load for an industrial painting operation can be predicted and/or determined when the following data are known:

- 1) The weight and volume of paint solids and organic volatiles that enter the plant.
- 2) The surface area of the merchandise painted and the film thickness of the applied paint solids. In other words, the volume of paint solids that are actually utilized and that leave the plant on the merchandise.

The difference between the volume of paint solids that enter the plant and the volume that leave the plant on the merchandise represents the solid and most of the semisolid waste generated by the painting operation.

The total volume of organic volatile material (paint components, solvents, thinners, additives, cleaning fluids, etc.) that enter the plant represents the organic volatile waste load generated by the painting operation.

PHASES

The scientific and trade literature was surveyed for the weights and volumes of the nonvolatile components (resins, pigments, etc.) of typical, widely used paints, and also for the weights and volumes of their organic volatile components (solvents, etc., exclusive of water).

The surveyed paint compositions were arranged into nine paint classes according to the application techniques (spray, dip, etc.) for which the paints had been formulated.

The paint application techniques were surveyed and studied for their expected transfer efficiency; i.e. their inherent unavoidable paint losses.

Mathematical equations were then developed by which the expected waste load for any planned painting operation can be predicted from the composition of the paint and the equipment and painting process to be used.

All these data were compiled into a preliminary 25 page report that was sent to about 30 experts in the field who were requested to provide their criticisms, suggestions, comments, etc. Where appropriate, the replies from these experts have been incorporated into this final report.

SECTION 2

CONCLUSIONS

The waste loads generated in painting processes for metal products are governed by four factors: 1) paint composition, 2) painting equipment, 3) curing method, and 4) miscellaneous unavoidable losses.

Solvents (water or organic volatiles) are an essential part of paint compositions. The more recently developed paint compositions --sometimes called "low polluting"-- are remarkably efficient in reducing the need for evaporation of water or organic volatile solvents, and they also reduce the quantity of semisolid waste generated.

The efficiency of the equipment for transferring the paint from the pot onto the surface of the merchandise varies from about 50% to almost 99%. The waste loads are, therefore, very much influenced by the type of painting equipment used.

Organic volatiles or water are emitted into the air by an evaporative process during the curing cycle. Comparatively small quantities of coreactants are also liberated during the cure of some commercial paints.

Most unavoidable losses are inherent with the method of applying the paint to the product. Additional unavoidable losses occur during normal handling of the equipment, cleaning of the equipment, and repair of defective paint coats (sanding, stripping, etc.).

A series of mathematical equations has been developed that allows the prediction of the waste loads for almost any kind and size of industrial painting operation or planned alternate, and for the determination of the actual waste loads calculated from production data.

In theory, the waste loads in painting operations could be significantly reduced by the judicious choice of paint, equipment, and curing method, and by the skill and techniques of operating personnel.

In practice, many efforts toward waste reduction in paint operations is currently underway, both for reasons of pollution law enforcement and for the economic savings possible. However, in order to ensure the quality of new coatings, it may take years of field testing before currently used paints and processes can be completely replaced by other more efficient ones.

SECTION 3

RECOMMENDATIONS

- 1) An effort should be made to familiarize government and industry personnel with the use of the mathematical prediction and actual determination of painting waste loads. Half or 1 day conferences should, therefore, be arranged for the presentation of the paint waste load computations.
- 2) Though an effort has been made to include typical paints and painting processes, a continuing effort should be made towards the detection of wasteful practices and encouragement of cheaper, more protective, and less wasteful practices.
- 3) Current literature does not refer to the nature of the malodorous fumes that are sometimes observed during painting operations. Laboratory devices should be developed for the study and generation of data towards the elimination of the fume-causing substances and/or practices.

SECTION 4

SURVEY PROCESSES AND DEVELOPMENT OF CALCULATIONS

GENERAL

Paint is a general term that is given to compositions that can be applied in comparatively thin, even layers onto solid surfaces where they convert into solid, adhesive, wear-resistant film coatings. Conventional filmforming materials are organic polymeric compounds; that is, materials containing carbon, hydrogen, oxygen, and sometimes minor quantities of other elements. Typical nonvolatile filmformer solids are known as acrylics, epoxies, urethanes, alkyds, etc. These generic names refer to the atomic arrangement of the elements which constitute the filmformer solid.

Filmformers, often called "resins", must be soluble in a liquid vehicle or meltable at reasonable temperatures so that they can be applied in thin, even layers onto the desired surface. Furthermore, filmformers must convert into solid film coatings through a "curing" process (drying, baking, etc.).

Most conventional filmformer solids, when they are used as the only nonvolatile component of a paint composition, will result in transparent film coatings. However, to meet the needs and desires of users, most paints are designed to hide the substrate of the material coated and to impart color to the finished merchandise. This is accomplished by the incorporation of pigments into the paint compositions. Pigments are usually nonvolatile solids intimately mixed or ground into the filmforming solids. Most pigments also increase the durability of the film coating.

Various other additives of volatile and/or nonvolatile nature may be incorporated in small quantities to paint compositions. These additives may facilitate the deposition and adhesion of the filmforming solids on the surface to be coated, enhance the curing process, effect a gloss or matte finish to the coating, etc.

Water is used in many paint compositions as most or part of the liquid component. Water is volatile and though the moisture emitted during painting operations may cause serious operational problems, water vapor is generally considered nonpollutional in nature. For the purpose of this study, attention has been directed specifically to the two classes of paint components that generate pollutional waste loads:

- 1) Organic Volatiles (OV) (solvents, thinners, plasticizers, and other liquid additives).

- 2) Nonvolatiles (NV) (resins, pigments, and other solid additives).

OBJECTIVES

The objectives of this study were to develop methods for:

- 1) The prediction of pollutional waste loads that will be generated by any size or type of planned industrial painting operation.
- 2) The determination of actual pollutional waste loads generated by any size or type of existing industrial painting operation.
- 3) A basis to be used for the selection of alternate paints or painting processes to reduce the predicted and/or actual pollutional waste loads in industrial painting operations.

SOURCES OF INFORMATION

The commercial paint manufacturing industry is highly competitive, therefore, the actual formulation of commercial paints is considered proprietary and, in most cases, will be released only as confidential information that may not be used in a study of this nature.

However, the resin manufacturers who supply basic materials to the paint manufacturers demonstrate the quality of their products by means of prototype formulations which are provided freely to the public. As a result, portions of this study have been based on the use of such detailed prototype formulations.

Where actual commercial paints have been used in calculation examples and tabulations, the organic volatile and nonvolatile components of the formulation have been lumped into single figures; that is, without consideration of the proportion of solvent, thinner, additives, resins, pigments, etc.

To insure the validity of the data developed using this approach and the relationship of prototype formulations to actual formulations of commercial paints on the market, the basic findings of the study were circulated to about 30 experts in the paint industry who were requested to provide their corrections, comments, and suggestions. The cooperation of these experts is greatly appreciated, and their replies have been incorporated in this final report as appropriate.

PAINT COMPOSITIONS

The ideal paint would be simply a nonvolatile filmforming substance that could be applied directly and evenly to any solid surface. Ideally, by use of this principle, no material would be lost in the transfer process, and no waste load would be generated (Figure 1).

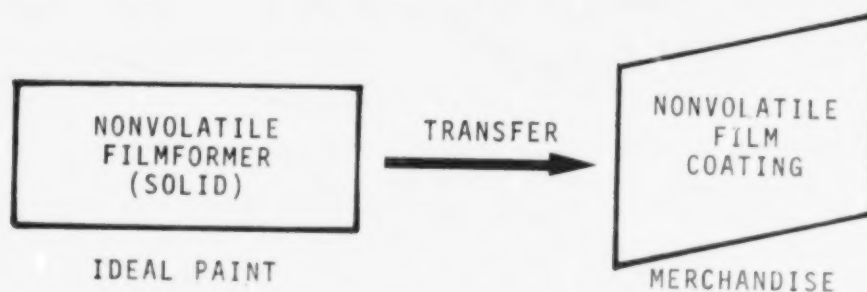


Figure 1. Film coating using an ideal nonvolatile filmformer solid.

There are certain newer classes of paints which aim at the use of this principle presently under development and a few are currently in use in limited applications. However, due to the time necessary to perfect and produce the required transfer equipment and the extensive field testing necessary to insure the quality of the new coatings, it will be a number of years before these new classes of paints widely replace the more conventional paints currently on the market.

These newer classes of paints present some minor pollutional problems in that a small organic volatile waste load is generated by the liberation of a small quantity of coreactants during the transfer and curing processes.

The vast majority of conventional paints currently on the market consist of compositions of nonvolatile filmformer solids mixed with a liquid vehicle (organic volatile solvents, water, or in some cases both) and are handled and applied in this liquid form. The use of paint compositions in liquid form provides two major advantages:

- 1) They allow for the use of a wide variety of transfer equipment and curing processes (spray, dip, roll, air drying, baking, etc.).
- 2) The viscosity of the paint composition as bought can be adjusted by increasing the ratio of liquids to solids. This allows for both an adaptation to the equipment and process used for the transfer operation and for control of the film coating layer applied to the merchandise.

The major disadvantage in using conventional liquid paint compositions is that the entire quantity of liquids is emitted into the air as waste loads during the transfer and curing processes. Only the nonvolatile solids deposited on the surface of the merchandise actually leave the plant as part of the finished product.

The greatest pollutional problems are encountered in the use of liquid paint compositions mixed with organic volatile solvents. The entire quantity of solvents in these paint compositions becomes organic volatile waste loads during the transfer and curing processes (Figure 2).

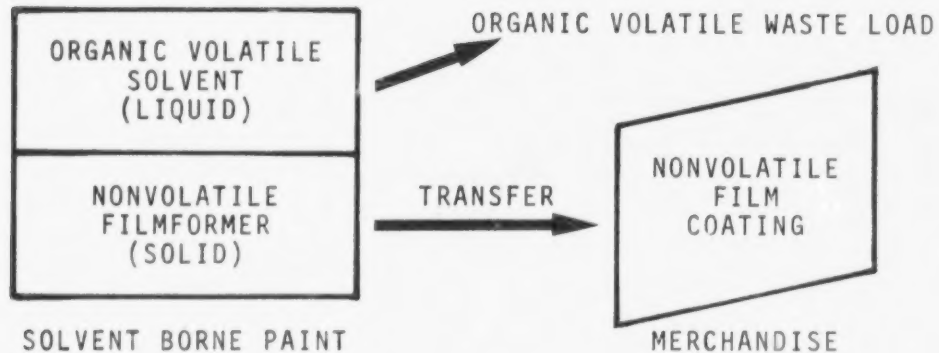


Figure 2. Film coating using organic volatile solvent based liquid paint compositions.

The generation of the organic volatile waste load from these paint compositions is through an evaporative process that occurs during the entire transfer and curing cycles of the painting operation. Emission of the waste load begins as soon as the paint composition is exposed to the air and continues until the film coating is fully cured.

Paint compositions mixed with water as the liquid component function in much the same manner as the organic volatile solvent based compositions. The entire quantity of water in the composition is emitted as a water vapor waste load during the transfer and curing processes (Figure 3).

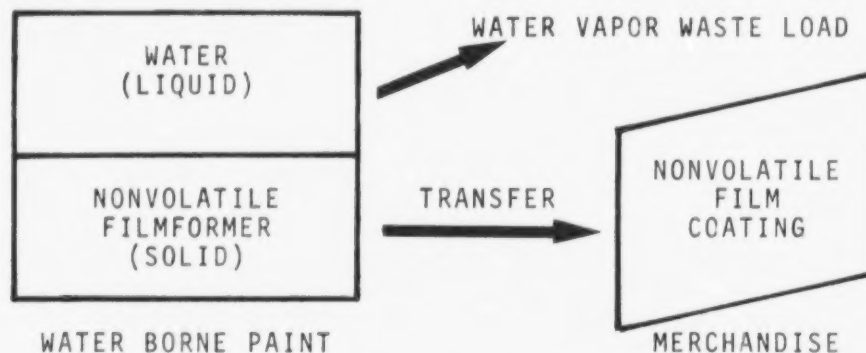


Figure 3. Film coating using water based liquid paint compositions.

Water vapor waste loads are generally considered nonpollutional in nature, therefore, little further consideration or discussion has been devoted to this factor in the remainder of this study. However, it should be noted that due to the corrosive nature of water vapor, this waste load may cause serious operational problems.

Paint compositions mixed with a combination of organic volatile solvents and water as liquid components generate both the organic volatile and water vapor waste loads described above (Figure 4).

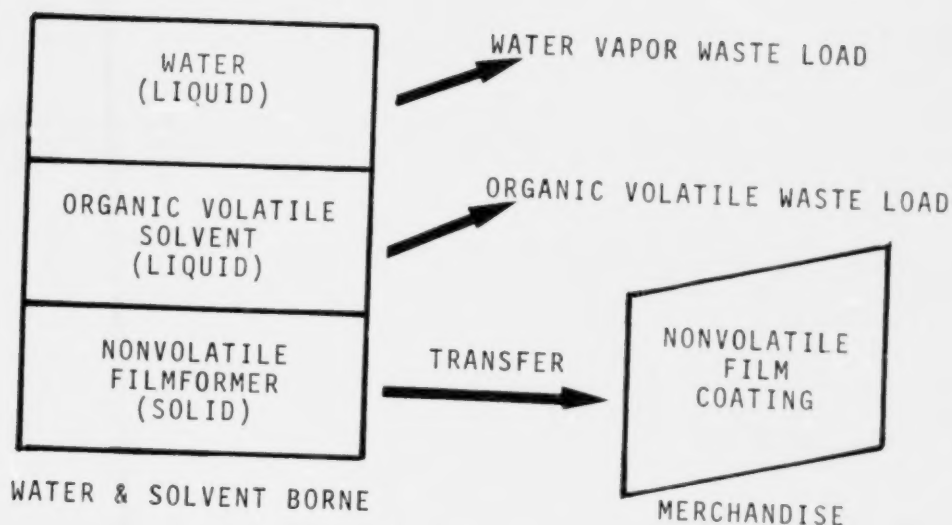


Figure 4. Film coating using organic volatile solvent and water based liquid paint compositions.

SELECTION OF PAINTS

Until quite recently, industrial paint users selected paint compositions and painting processes on the primary basis of the quality of the film coating and the basic cost of the paint materials. Today, environmental factors and the energy consumed by the transfer and curing processes must also be given weighted consideration in the selection process. As a result, the paint manufacturing industry is currently engaged in extensive efforts to develop more desirable paint compounds and more efficient painting processes.

The quality and durability of the film coating remains the primary consideration of the ultimate paint consumer. It generally takes about five years of product experimentation and extensive laboratory and field testing before an industrial paint user can have reasonable assurance that a new paint will meet quality, cost, environmental, and energy requirements. Therefore, an industrial switch to newer classes of paints and painting processes is expected to be a slow and cautious process.

The reason for the long periods of laboratory, field, and sometimes outdoor exposure testing is to subject the film coatings to the same conditions they will meet when used for the actual purpose for which they are designed.²

Obviously, if a paint manufacturer is expected to guarantee a film coating for a service life of two years, laboratory and field testing will require a minimum of two years. In most cases, a film coating is applied to hundreds or even thousands of pieces of material to be used in the tests. If the film

² Gardner, H. A., and Sward, G. G. ASTM Paint Testing Manual, 13th Edition, American Society for Testing and Materials, Philadelphia, Pa. 1972, pg 251-494.

coating fails on an unacceptable number of pieces during the tests and the paint composition or painting process is changed for improvement, a new series of tests must be initiated.

In the case of paints made for use on merchandise designed for outdoor use extensive exposure tests to a wide range of climatic conditions is frequently required.

Even after a new paint has been developed in the laboratory or pilot plant and has met all requirements of quality, cost, environment, and energy, still further delays may be expected before it is widely adopted. It may be several years before the raw materials are available or can be produced in sufficiently large quantities. It may also require time for the development, planning, capital investment, manufacture, and installation of the required equipment for the new painting process.

BUYING AND USING PAINTS

The industrial user normally buys paint as a composition consisting of nonvolatile filmforming solids and sacrificial liquids. During the painting operation the nonvolatile solids are applied to the surface of the merchandise and the liquids are emitted as waste loads. The film coating on the merchandise must meet certain specifications, such as, durability, color, hardness, gloss, corrosion resistance, etc., and in many cases film thickness.

There are a number of factors which must be determined before an industrial paint user can figure the cost of a painting operation and make a decision as to what quantity of what paint to buy.

First, the volume of nonvolatile solids required to coat the surface area of the merchandise to the specified thickness must be determined. This can be found by multiplying the total surface area by the thickness of the film coating.

Next, the volume of nonvolatile solids contained in a purchased unit of paint composition must be known. Commercial paint compositions are usually sold by weight, and the quantity of nonvolatile solids in the composition is also often given by weight. If this is the case, the weight of the nonvolatile solids must be converted to volume.

From the above factors the quantity and cost of the paint composition for a specific operation can be calculated. Suppose several paint manufacturers offer paint compositions which meet all the requirements of the film coating but vary in formulation and cost. Obviously the most economical composition to buy is that which contains the most nonvolatile solids at the lowest cost. However, this is only one of the factors in the over-all cost of the painting operation.

Since all liquids in paint compositions are emitted as waste loads during painting operations, the costs for controlling these waste loads is a factor in the over-all cost of the painting operation. The most serious pollutional

waste loads are those generated by organic volatile solvents. From an environmental standpoint it might appear that the least polluttional paint composition to buy would be that which contains the least volume of organic volatile solvent. However, most paint compositions are sold with nonvolatile concentrations too high to be used in most painting processes and must be "thinned" by the addition of more liquids before they are used. Waste loads must be calculated by the volume of liquids in the composition "as used" rather than "as bought". The cost of the additional liquids must also be figured into the over-all cost of the painting operation.

The use of paint compositions that use water as part or all of the liquid content may reduce or eliminate polluttional waste loads. However, the cost of overcoming the operational problems, such as corrosion, caused by the water vapor waste load, and the cost of energy to evaporate the water may exceed the costs of controlling environmentally polluttional waste loads.

Energy consumption required for transfer and curing processes is becoming an ever greater factor in the over-all cost of a painting operation. If the present energy shortage trend continues, it may become more than a matter of cost and become a matter of availability.

Another major factor in the calculations of the quantity and cost of materials and the generation of waste loads is the transfer efficiency of the equipment and process used in the painting operation. Unavoidable losses of part of the total volume of nonvolatile solids occurs in all painting processes. For example, if the transfer efficiency of a painting process is only 50% it means that only half of the nonvolatile solids in the paint composition "as used" is actually deposited on the surface of the merchandise; the other half becomes nonvolatile waste.

The final factors which must be considered are other minor unavoidable losses such as cleaning and repair of equipment, sanding or stripping to repair or remove defective coatings, and accidental spillage or wastage.

UNITS OF MEASUREMENT

Metric system units of measurement have been used as the primary standard throughout this study. In most cases examples have also been shown using U.S. standard units of measurement for better understanding.

As stated previously, paint compositions may be bought in either metric or U.S. units of weight (kilograms or pounds) or volume (liters or gallons). The quantity of nonvolatile solids and liquids in the composition may also be provided in units of weight or volume, or may be expressed in percentages of the total units.

In order to use the equations developed in this study the industrial paint user must convert the known units of weight or volume to the other factor for specific calculations. The quantity of nonvolatile solids required to form the film coating on the surface of the merchandise must be calculated in units of volume (area coated x thickness of film = volume). The volume

of volatile waste loads, particularly those generated by organic volatile solvents, does not represent meaningful data due to large variances in density possible from the range and variety of liquids used in paint compositions. Normally, all waste loads are calculated in weight units, though the volume of semisolid waste loads may be desired in some cases. The method for developing calculations is shown schematically in Figure 5.

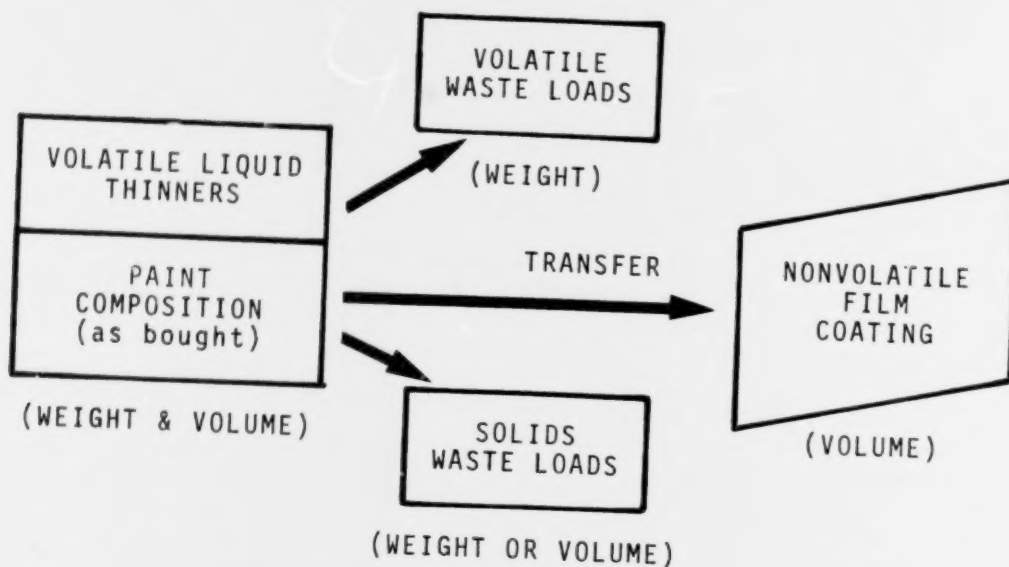


Figure 5. Calculation Schematic

VOLUME CALCULATIONS

A constant (K) factor can be developed to represent the maximum area that can be film coated to a specified thickness by a standard metric or U.S. unit of volume of nonvolatile (NV) paint solids. This K factor is developed on the assumption that the entire volume of NV solids are transferred to the surface of the merchandise, that is, 100% transfer efficiency.

Since there are some unavoidable NV losses in all painting processes, the maximum area coverage will never be achieved in actual operation. However, by using maximum data, computations may be developed for the following three purposes:

- 1) Cost comparison between available paint compositions by direct comparison of costs per unit volume of NV.
- 2) The maximum area that may be coated to a specified thickness in any painting operation by a given volume of NV. (Shown in Equation 1.)
- 3) The minimum volume of NV required to coat a specified area to a specified thickness. (Shown in Equation 2.)

The volume calculations which follow have been developed using the metric and U. S. Standard measurement units commonly used by both the paint manufacturing industry and industrial paint users (Table 1).

TABLE 1. COMMONLY USED PAINT MEASUREMENT UNITS

MEASUREMENT	METRIC	U. S. STANDARD
Length	1 m = 100 cm	1 ft = 12 in
Area	1 m ² = 10,000 cm ² or 1 x 10 ⁴ cm ²	1 ft ² = 144 in ²
Thickness	1 μm = .0001 cm or 1 x 10 ⁻⁴ cm	1 mil = .001 in or 1 x 10 ⁻³ in
Volume	1 l = 1,000 cm ³ or 1 x 10 ³ cm ³	1 gal = 231 in ³

Using these units of measurement, the theoretical maximum area that can be covered by 1 liter of NV 1 μm thick, and by 1 gallon of NV 1 mil thick, can be established. (volume / thickness = area)

METRIC

$$\frac{1 \text{ l}}{1 \text{ μm}} = \frac{1 \times 10^3 \text{ cm}^3}{1 \times 10^{-4} \text{ cm}}$$

$$= 1 \times 10^7 \text{ cm}^2$$

convert to m²

$$= \frac{1 \times 10^7 \text{ cm}^2}{1 \times 10^4 \text{ cm}^2}$$

$$= 1,000 \text{ m}^2$$

U. S. STANDARD

$$\frac{1 \text{ gal}}{1 \text{ mil}} = \frac{231 \text{ in}^3}{1 \times 10^{-3} \text{ in}}$$

$$= 231 \text{ in}^2 \times 10^3$$

convert to ft²

$$= \frac{231 \text{ in}^2 \times 10^3}{144 \text{ in}^2}$$

$$= 1,604 \text{ ft}^2$$

Equation 1

The following equation may be used to calculate the maximum surface area that may be coated to a specified thickness by a given volume of NV:

$$A_{\text{max.}} = (K/t) \times v \text{ NV}$$

where (metric)

$$A_{\text{max.}} = \text{maximum possible area in m}^2$$

$$K = 1,000 \text{ m}^2 \times 1 \text{ } \mu\text{m/liter}$$

$$t = \text{film thickness in } \mu\text{m}$$

$$v = \text{volume in l}$$

or, where (U. S. Standard)

$$A_{\text{max.}} = \text{maximum possible area in ft}^2$$

$$K = 1,604 \text{ ft}^2 \times 1 \text{ mil/gallon}$$

$$t = \text{film thickness in mil}$$

$$v = \text{volume in gal}$$

Example 1

To calculate the maximum area that can be coated with a film 38.1 μm (1.5 mil) thick with a quantity of paint containing 64 liters (16.9 gal) of nonvolatile (NV) solids:

$$\begin{aligned} A_{\text{max.}} &= \frac{1,000}{38.1} \times 64 & \frac{(1,604)}{(1.5)} \times (16.9) \\ &= 1,680 \text{ m}^2 & (18,072 \text{ ft}^2) \end{aligned}$$

Equation 2

The following equation may be used to calculate the minimum volume of NV required to coat a given surface area to a specified thickness:

$$v_{\text{NV min.}} = (A_p/K) \times t$$

where

$$v_{\text{NV min.}} = \text{minimum volume of nonvolatiles in l (gal)}$$

$$A_p = \text{area to be painted in m}^2 \text{ (ft}^2\text{)}$$

$$K = 1,000 \text{ m}^2 \times 1 \text{ } \mu\text{m/l (1,604 ft}^2 \times 1 \text{ mil/gal)}$$

$$t = \text{film thickness in } \mu\text{m (mil)}$$

Example 2

To calculate the minimum volume of nonvolatiles (NV) necessary to cover a surface area of 9,295 m² (100,000 ft²) with a film 19 μm (.75 mil) thick:

$$\begin{aligned} v_{NV_{min.}} &= \frac{9,295}{1,000} \times 19 & \frac{(100,000)}{(1,604)} \times (.75) \\ &= 176.6 \text{ l} & (46.8 \text{ gal}) \end{aligned}$$

Summary

It should be noted that "Maximum Area" and "Minimum Volume" have been emphasized in computing the consumption of nonvolatile solids (Figure 6).

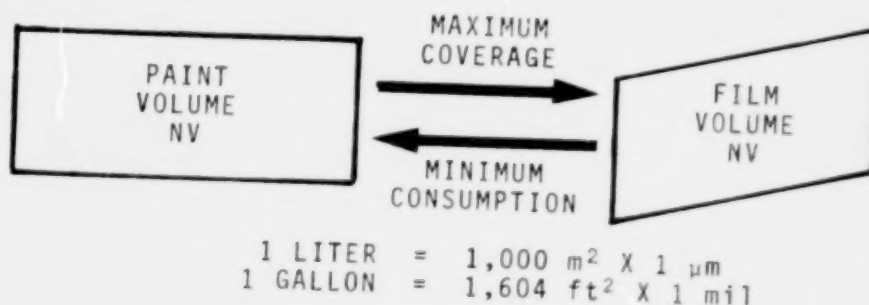


Figure 6. Maximum coverage equals minimum consumption.

Since there are some unavoidable losses of NV in all painting processes, maximum coverage with a minimum volume will never be achieved. The discussion of these losses is one of the objectives of this study and is provided in the following sections of this report.

ORGANIC VOLATILES IN PAINTS

All paint compositions contain some amount of organic volatile (OV) material. Even the so-called "water borne" paint compositions contain a moderate amount of OV. These OV materials are necessary to provide compatibility of components during the manufacture of the compositions and to facilitate the application of the nonvolatile (NV) solids to the desired surface. Comparatively, the largest amount of OV material is usually found in paint compositions designed for use in spray painting operations, while the least amount is found in dry paint powder compositions.

As Bought

Most paint manufacturers list the various components in their paint compositions as volume percentages (vol%). For example, a certain water borne paint (Code 1Aw 1) surveyed during this study is listed by the manufacturer as containing:

26.6 vol% NV
15.1 vol% OV
58.3 vol% water

Since the volume of the NV components is the basis used for buying and using paint compositions, the vol% of NV can be established as a measurement unit (liter or gallon) of volume. The vol% relationship of all components can then be shown as units of volume: (Figure 7)

1.000 vol (liter or gallon) NV
0.568 vol (liter or gallon) OV
2.192 vol (liter or gallon) water

3.760 vol (liter or gallon) paint composition

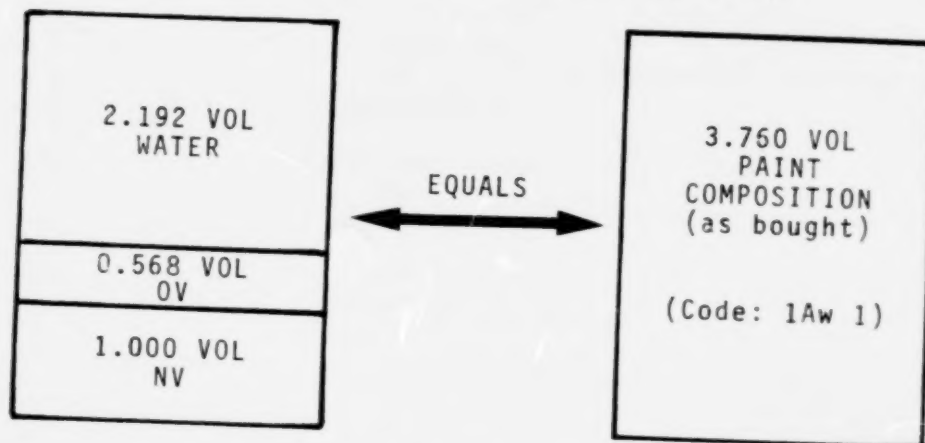


Figure 7. Volume relationship of paint components.

As shown above, in order to provide one unit volume (liter or gallon) of NV for a painting operation it is necessary to buy and use 3.76 unit volumes (liters or gallons) of this particular paint composition (Code 1Aw 1). The entire volumes of OV and water are emitted during the painting operation as OV and water waste loads as previously shown in Figure 4.

As Used

Most commercial paint compositions are manufactured and sold for use in a variety of painting processes. Many of these compositions contain a solids concentration too high to be used by most painting equipment and processes. Therefore, the user must add an additional volume of liquid (OV solvent and/or water) to reduce the viscosity as necessary for his specific painting operation.

When "thinners" are added to a paint composition "as bought" the volume of NV remains the same, but the volume of OV and/or water and the total volume is increased proportionally. In order to calculate waste loads it is necessary to correct the vol% and volume relationship to reflect the actual "as

used" composition. For example, a certain solvent borne paint (1As 6) surveyed is listed as containing:

<u>As Bought</u>	<u>As Used</u>
36.4 vol% NV	28.6 vol% NV
63.6 vol% OV	71.4 vol% OV

The vol% of all components, both as bought and as used, can then be shown as units of measure: (Figure 8)

<u>Buy</u>	<u>Use</u>
1.000 vol	1.000 vol (1 or gal) NV
1.747 vol	2.496 vol (1 or gal) OV
2.747 vol	3.496 vol (1 or gal) paint composition

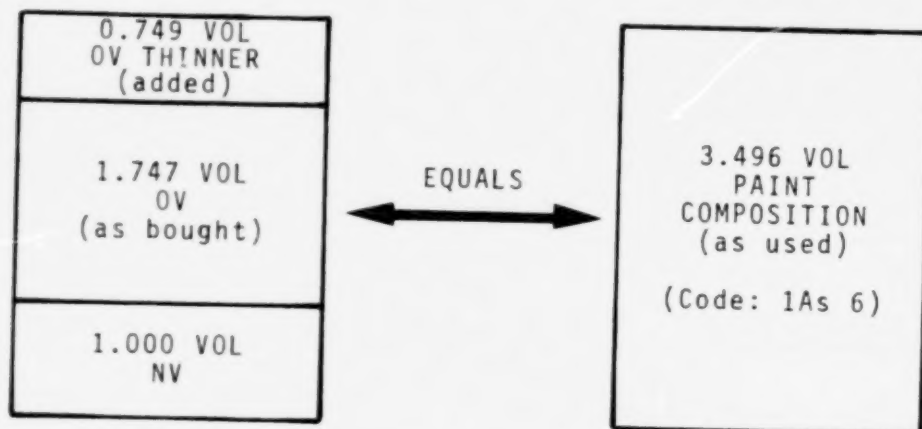


Figure 8. Volume relationship of paint components "as used".

The total paint composition under the "buy" column can be used to calculate the quantity of paint that must be bought. The difference in the volume of OV between the buy and use columns can be used to calculate the quantity of thinner that must also be bought. The total volume of OV under the "use" column becomes an OV waste load during painting and curing processes.

ORGANIC VOLATILE CALCULATIONS

Since the volume of NV is the controlling factor in the quantity of paint composition required in a painting operation, the ratio of OV to NV in the composition is required to determine the OV waste load. This ratio must be established for the OV and NV components in the mixture "as used". For solvent borne paint compositions, such as 1As 6 used in the example above, the total "as used" volume contains only OV and NV components. This example shows a ratio of 2.496 vol (liter or gallon) of OV for each vol (liter or gallon) of

NV in the "as used" composition. For water borne paint compositions, such as 1Aw 1 used in the "as bought" example and shown in Figure 7, it may be desired to establish a vol% ratio between just the OV and NV components and disregard the water in the composition (Figure 9).

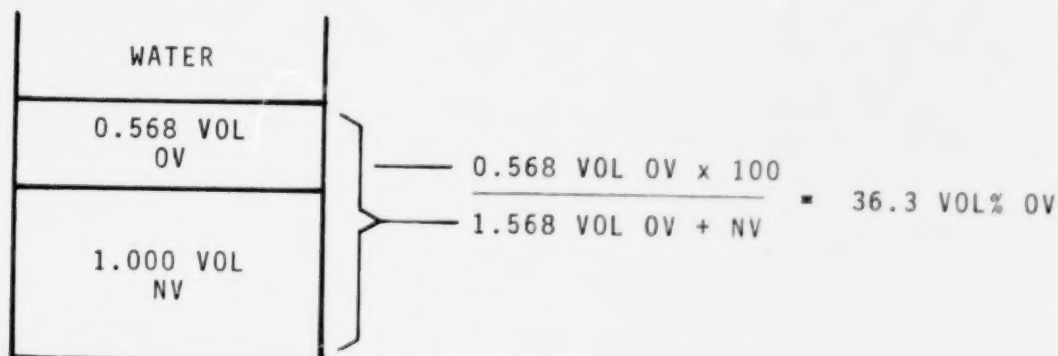


Figure 9. Vol% ratio of OV to NV components.

For OV waste load calculations, the vol% ratio of OV to NV must first be reduced to the volume (liter or gallon) of OV associated with 1 volume (liter or gallon) of NV (Equation 3) and then the volume (liter or gallon) converted to weight (kilogram or pound) (Equation 4).

Equation 3

The following equation may be used to calculate the volume (liter or gallon) of OV associated with 1 volume (liter or gallon) of NV:

$$vOV = \frac{\text{vol\% OV}}{(100 - \text{vol\% OV})} \quad \text{or} \quad \frac{\text{vol\% OV}}{\text{vol\% NV}}$$

where

$$vOV = \text{volume of OV in liters or gallons}$$

Example 3

The volume of OV associated with 1 volume of NV in paint composition 1Aw 1 can be found by using the vol% ratio established in Figure 9:

$$vOV = \frac{36.3}{(100 - 36.3)} = \frac{36.3}{63.7} = 0.57 \text{ (liter or gallon)}$$

or, by using the original vol% ratio of OV to NV given on page 18:

$$vOV = \frac{15.1 \text{ vol\% OV}}{26.6 \text{ vol\% NV}} = 0.57 \text{ (liter or gallon)}$$

Equation 4

The following equation may be used to calculate the weight (kilograms or pounds) of a given volume (liter or gallon) of OV:

$$wOV = vOV \times dOV$$

where

$$wOV = \text{weight in kilograms or pounds}$$

$$vOV = \text{volume in liters or gallons}$$

$$dOV = \text{density weight for 1 volume unit in kg/l or lb/gal}$$

Example 4

The weight of OV associated with 1 volume of NV in paint composition 1Aw 1 can be found if the density weight of the OV is known:

$$\begin{aligned} wOV &= 0.57 \times 0.91 & (0.57 \times 7.5) \\ &= 0.52 \text{ kg} & (4.3 \text{ lb}) \end{aligned}$$

where

$$dOV = 0.91 \text{ kg/l} \quad (7.5 \text{ lb/gal})$$

Variations of Equation 4

Paint manufacturers may show the ratio of OV to NV in their compositions in several different ways. Frequently the ratio is expressed as "weight (kg or lb) of OV per volume (liter or gal) of paint composition less water"; i.e. $wOV/(vOV + vNV)$. In other cases the ratio is expressed as "weight (kg or lb) of OV per volume (liter or gal) of NV"; i.e. wOV/vNV . These ratios can each be converted to the other by use of Equations 4a and 4b respectively.

Equation 4a--

The following equation can be used to find the weight of OV associated with 1 volume unit of NV when the $wOV/(vOV + vNV)$ and dOV are known:

$$w'OV/v'NV = \frac{wOV}{\left(1 - \frac{wOV}{dOV}\right)}$$

where

$$w'OV/v'NV = \text{weight (kg or lb) of OV per 1 volume (l or gal) of NV}$$

Example 4a--

$$\begin{aligned}
 w'OV/v'NV &= \frac{0.348}{\left(1 - \frac{0.348}{0.930}\right)} & \frac{(2.90)}{\left(1 - \frac{(2.90)}{(7.75)}\right)} \\
 &= \frac{0.348}{0.626} & \frac{(2.900)}{(0.626)} \\
 &= 0.556 \text{ kg OV/1 NV} & (4.63 \text{ lb OV/gal NV})
 \end{aligned}$$

where

$$\begin{aligned}
 wOV &= 0.348 \text{ kg/1 (OV + NV)} & (2.9 \text{ lb/gal (OV + NV)}) \\
 dOV &= 0.93 \text{ kg/1} & (7.75 \text{ lb/gal})
 \end{aligned}$$

Equation 4b--

The following equation can be used to find the weight of OV associated with 1 volume unit of (OV + NV) when the wOV/vNV and dOV are known:

$$w'OV/(v'OV + v'NV) = \frac{wOV}{\left(1 + \frac{wOV}{dOV}\right)}$$

where

$$w'OV/(v'OV + v'NV) = \text{weight (kg or lb) of OV per 1 volume of (OV + NV)}$$

Example 4b--

$$\begin{aligned}
 w'OV/(v'OV + v'NV) &= \frac{0.556}{\left(1 + \frac{0.556}{0.930}\right)} & \frac{(4.63)}{\left(1 + \frac{(4.63)}{(7.75)}\right)} \\
 &= \frac{0.556}{1.598} & \frac{(4.63)}{(1.598)} \\
 &= 0.348 \text{ kg/1 (OV + NV)} & (2.9 \text{ lb/gal (OV + NV)})
 \end{aligned}$$

where

$$\begin{aligned}
 wOV &= 0.556 \text{ kg/1 NV} & (4.63 \text{ lb/gal NV}) \\
 dOV &= 0.93 \text{ kg/1} & (7.75 \text{ lb/gal})
 \end{aligned}$$

SECTION 5

PAINTING METHODS AND EQUIPMENT

GENERAL

It was shown in the previous Section that the first factor in paint calculations is the ratio of organic volatiles to nonvolatile solids in the paint composition. The next factor to be considered is the "transfer efficiency" of the painting method and equipment used to apply the paint composition to the surface of the merchandise.

The most commonly used methods and equipment used for painting operations by the metal fabricating and finishing industry were surveyed and are discussed in this Section.

SPRAY PAINTING

The principle of spray painting is to break up the liquid paint composition into tiny droplets and propel them through the air onto the surface of the merchandise to be coated. There are several methods for atomizing the paint composition and there is a variety of spray painting equipment currently in use.

Air Atomization

In this method a jet of compressed air impinges on a stream of liquid paint which emerges from an orifice in the tip of the spray gun. The air jet atomizes the paint and propels (transfers) the droplets onto the surface of the merchandise (Figure 10).

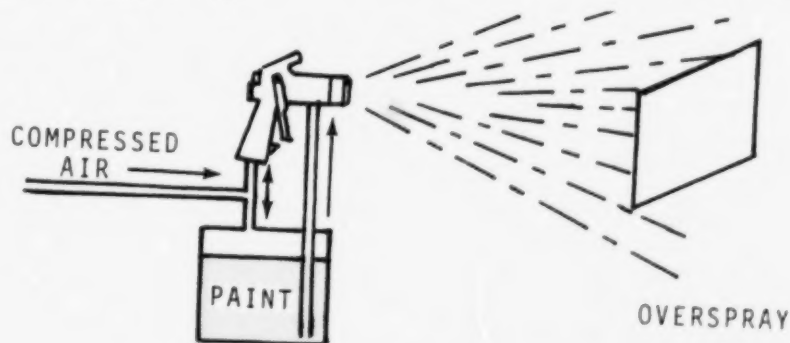


Figure 10. Air atomized spray.

Conventional spray painting using the air atomized method has the lowest "expected transfer efficiency" (about 50%) of all the methods surveyed. This low transfer efficiency is due in part to the unavoidable overspray necessary to achieve full coverage of the film coating on the merchandise and in part to a factor called "air back bounce" which prevents many of the paint droplets from reaching the surface of the merchandise.

Pressure Atomization

In this method the liquid paint is forced through a small diverging orifice at a relatively high pressure of about 600 psi. The paint emerges from the orifice as a fine spray with sufficiently high kinetic energy to propel (transfer) it through the intervening air onto the surface of the merchandise (Figure 11).

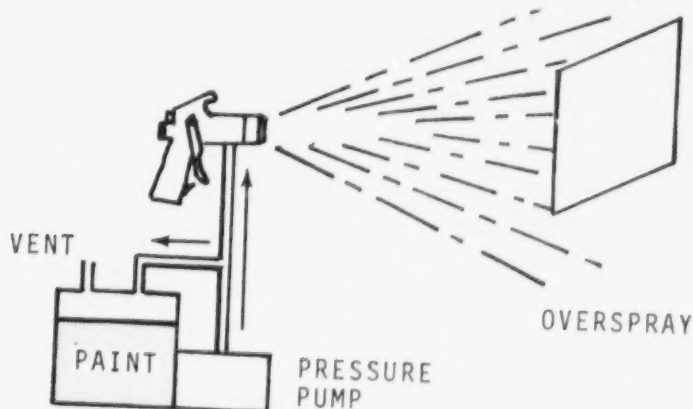


Figure 11. Pressure atomized spray.

The pressure atomized method has a higher "expected transfer efficiency" (about 65%) than the air atomized method. Though relatively the same amount of unavoidable overspray is necessary to achieve full coverage, the "air back bounce" factor is considerably reduced due to the smaller mass volume of air movement.

Electrostatic Field Assisted Spray Painting

In this method the atomized paint is given a polarized high voltage electrical charge (usually about 100,000 volts) at or near the point where it emerges from the paint gun and the merchandise is electrically grounded to the opposite polarity of the power source. Thus, the charged paint particles are electrically attracted to the surface of the merchandise (Figure 12).

By using electrostatic field assistance in either the air atomized or pressure atomized method, the "expected transfer efficiency" can be increased to approximately 85%. Both the necessary unavoidable overspray and "air back bounce" factors are appreciably overcome by the electrical attraction of the paint particles to the surface of the merchandise.

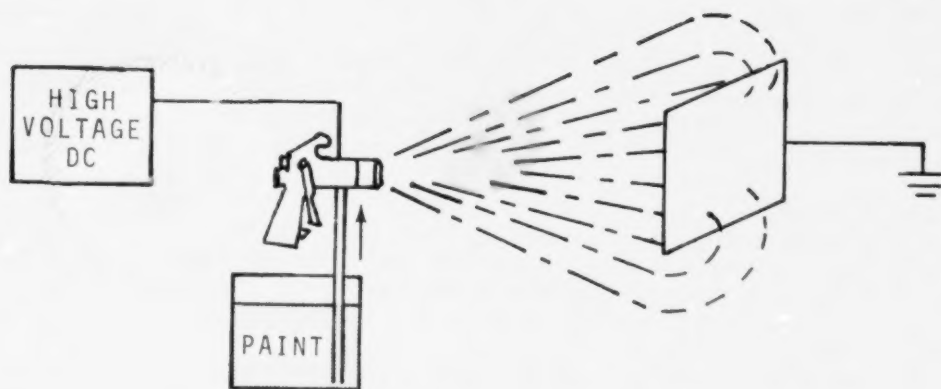


Figure 12. Electrostatic field assisted spray painting.

Centrifugal Atomization

In the most commonly used centrifugal atomization method, liquid paint is oozed onto the center inside surface of a rapidly rotating bell. The centrifugal force of the rotating bell moves the paint to the open end where it passes through an electrostatic field and emerges as a charged, atomized spray. As the spray emerges, the electrostatic field directs (transfers) it to the surface of the merchandise (Figure 13).

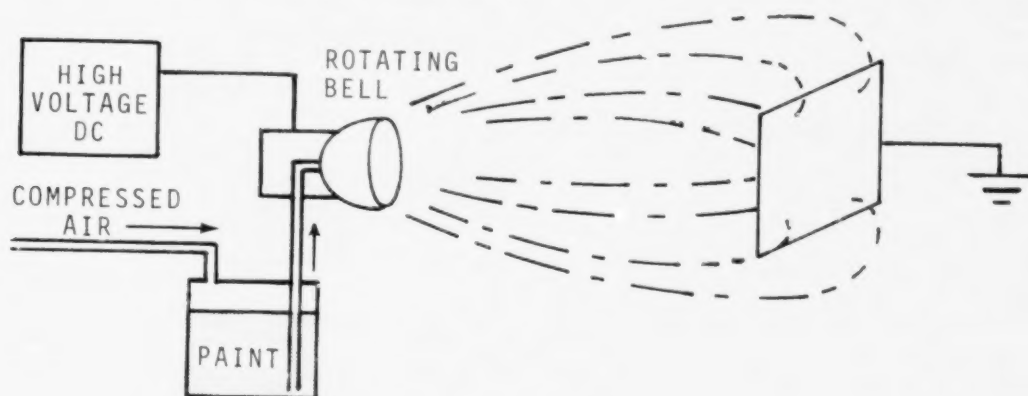


Figure 13. Centrifugal atomized spray.

The centrifugal atomization has the highest "expected transfer efficiency" of all spray painting methods surveyed (about 93%).

A common variation of the centrifugal atomization method uses a horizontally rotating disk instead of the bell described above. This variation has about the same transfer efficiency and provides a wider coverage area. In this method the merchandise is usually carried by a conveyor in a horse shoe shaped loop around the disk.

Associated Equipment

Due to the airborne solid and semisolid wastes generated by spray painting operations they must be performed in a confined area. A paint spray booth may simply be an area enclosed on three sides with an exhaust fan and filter in an overhead hood, or it may be a much more elaborate arrangement.

Strippable Coatings--

There are several products on the market that can be applied to the inner surfaces of spray booths. When a layer of waste has accumulated on these coatings, they can be peeled off along with the waste and a new coating applied.

Water Bath Spray Booth--

In this type of booth, the sides consist of a series of baffles over which a curtain of water cascades (Figure 14).

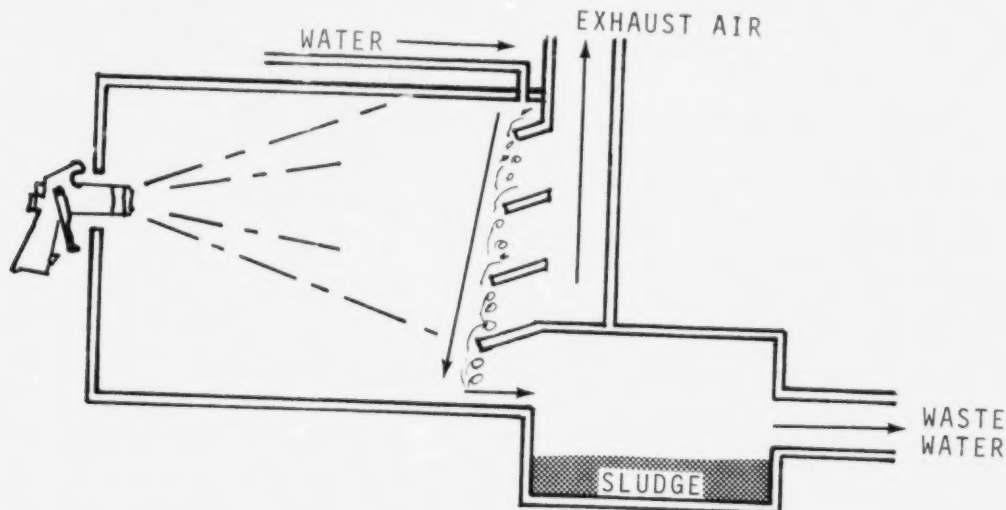


Figure 14. Water bath spray paint booth.

The airborne solids are absorbed by the water curtain so that the exhaust air contains only volatile wastes. The solids form a sludge in an associated tank or reservoir and in some limited circumstances may be reclaimed. Waste water from such methods may contain both organic liquids and solid contaminants and require additional treatment.

Hot Melt Spray Paints

There are a number of spray paint compositions manufactured that are designed to be preheated before use. These paints have such high concentrations of solids that the viscosity at ambient temperatures is too high to be handled by spray devices, but when preheated thin sufficiently for normal application.

These paint compositions are satisfactory for use in any of the spray methods described above and have approximately the same "expected transfer efficiency" as other paints used by the same method.

DIP COATING

In the dip coating method the merchandise is actually submerged in a container of liquid paint and then lifted back out. The excess paint drips off the merchandise either directly back into the paint container or into a drip recovery tray. Dip coating of rigid, profiled merchandise requires that each piece be submerged individually (Figure 15).

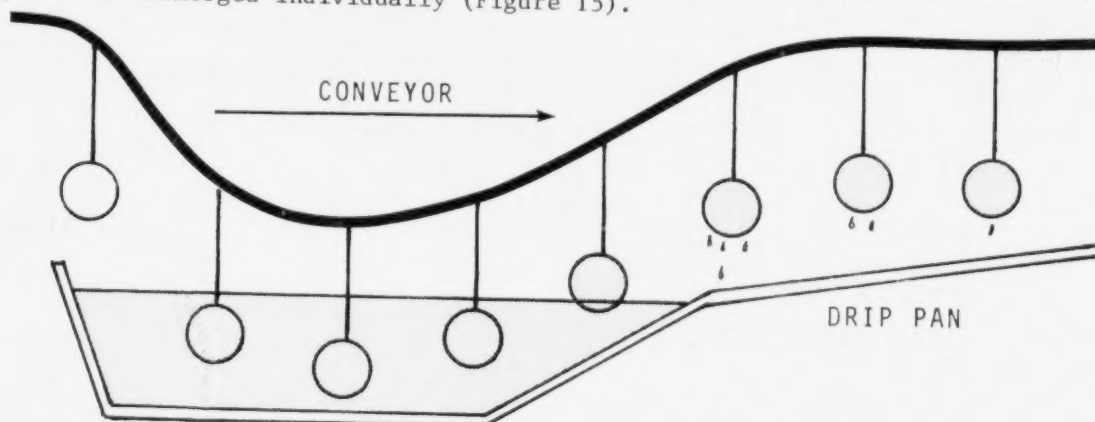


Figure 15. Dip coating rigid, profiled merchandise.

The drip off process is sometimes aided by the use of a high voltage electrostatic field which is effective in eliminating drops of paint that might otherwise form on the bottom of the merchandise.

Flexible, essentially unprofiled merchandise such as coil stock or wire is dip coated by a continuous process (Figure 16).

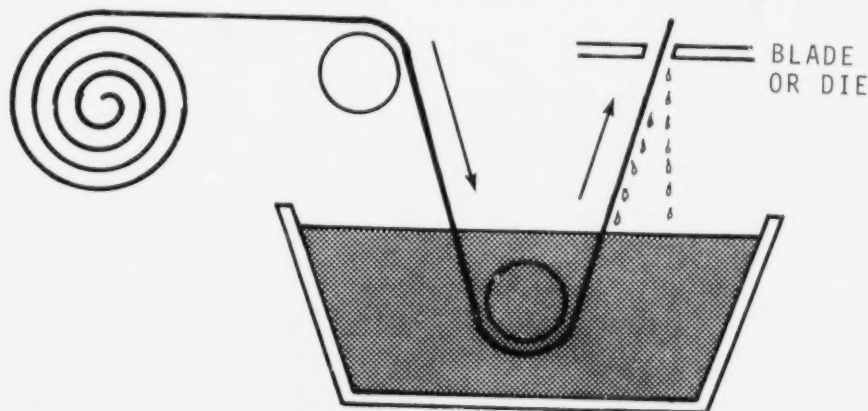


Figure 16. Dip coating flexible, unprofiled merchandise.

The drip off process from continuous material is usually aided by passing the merchandise through a blade or die that serves to wipe off excess paint.

The "expected transfer efficiency" for both the dip coating methods cited above is in the range of 75 to 90%.

FLOW COATING

In the flow coating method liquid paint is poured over the top of the merchandise and allowed to drip off the bottom. The merchandise is positioned over a container of paint, part of the paint is pumped to a dispensing head over the merchandise, the paint flows over the merchandise forming a coating, and the excess drips back into the container (Figure 17).

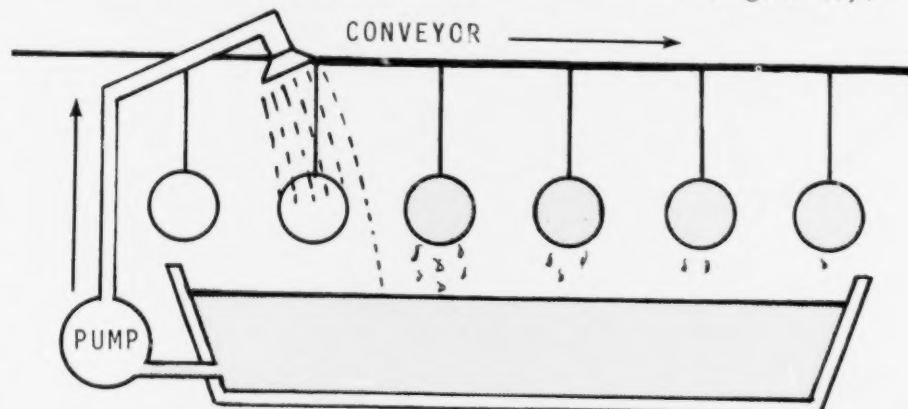


Figure 17. Flow coating.

Drip off is sometimes aided by use of a high voltage electrostatic field. The "expected transfer efficiency" for the flow coating method is about the same as for the dip coating method (75 to 90%).

CURTAIN COATING

The curtain coating method is similar in principle to the flow coating method. Curtain coating is usually used to paint flat, relatively thin pieces of merchandise. The merchandise is passed beneath a paint trough that has a slit in the bottom that is perpendicular to the direction of movement of the merchandise (Figure 18).

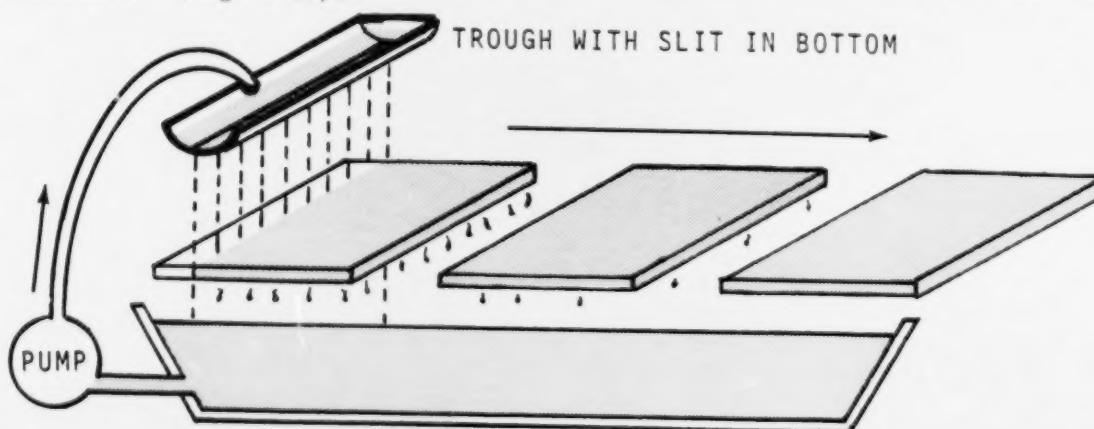


Figure 18. Curtain coating.

Liquid paint in the paint trough flows through the slit by gravity onto the merchandise as it passes below. Excess paint flow and drip off is caught in a container positioned below the merchandise. The system usually contains a circulating pump which recycles the paint from the container below the merchandise back up into the trough and maintains the paint level in the trough.

The "expected transfer efficiency" for the curtain coating method is about the same as for the dip and flow coating methods (75 to 90%).

ROLL COATING

In this method liquid paint is applied by a transfer roll directly to the surface of the merchandise. This method can be used to paint any flat material, rigid or flexible, individual pieces or continuous sheets, to one side or to both sides simultaneously. The principle of roll coating is to cover the surface of the transfer roll with liquid paint, control the amount of paint on the surface of the transfer roll by means of a metering roll, and then to transfer the paint from the transfer roll directly to the surface of the merchandise by direct contact (Figure 19).

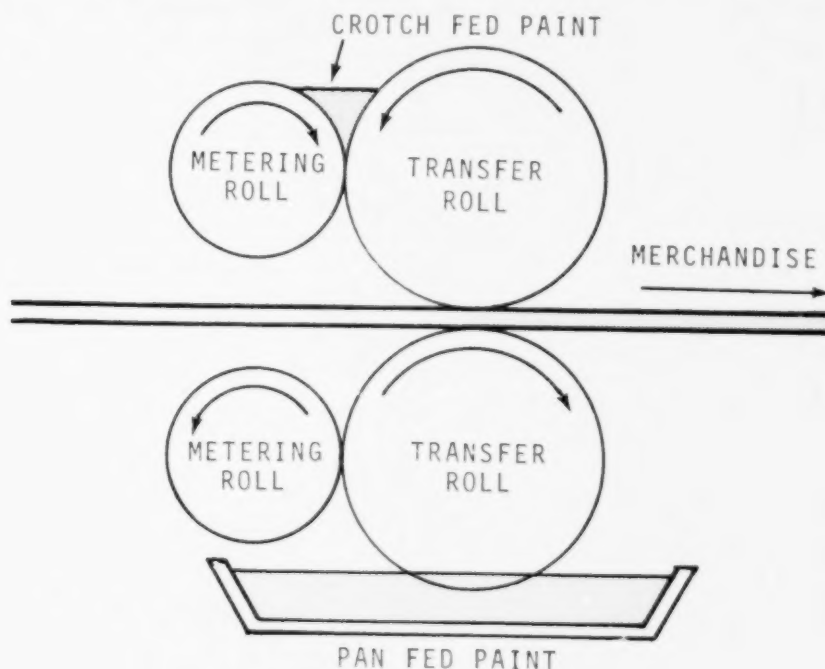


Figure 19. Roll coating.

The above illustration shows basically a typical arrangement for roll coating both sides of a continuous sheet of material simultaneously. In a typical arrangement for coating only one side, the transfer and metering rolls on the opposite side would be replaced by a single "nip" roll for the purpose of maintaining pressure between the transfer roll and the material.

There are a number of variations to the typical method of roll coating shown in Figure 19. For example, a better application of the paint to the surface of the merchandise is sometimes achieved by "reverse roll coating". In other words, at the point of contact between the transfer roll and the material the transfer roll is rotating in the opposite direction from the direction of travel of the material. This causes a "wiping" action at the point of transfer.

The "expected transfer efficiency" for the roll coating method is in the range of 90 to 98%. Another advantage of this method is that roll coating paints are used at relatively high viscosity and, therefore, contain a comparatively low ratio of organic volatile solvents to nonvolatile solids.

ELECTROCOATING

In this method the merchandise is submerged into a dilute (low viscosity) dispersion of specially formulated nonvolatile paint solids mixed with water. A low voltage (50 to 500 volt), direct current electrostatic field is applied, which attracts the nonvolatile paint particles to the surface of the merchandise, where they form a highly viscous deposit. The merchandise is then lifted out of the electrocoating bath and subjected to several ultrafiltrate rinse stages. Any droplets of paint lifted out of the bath on the newly painted surface are rinsed back into the dip tank (Figure 20).

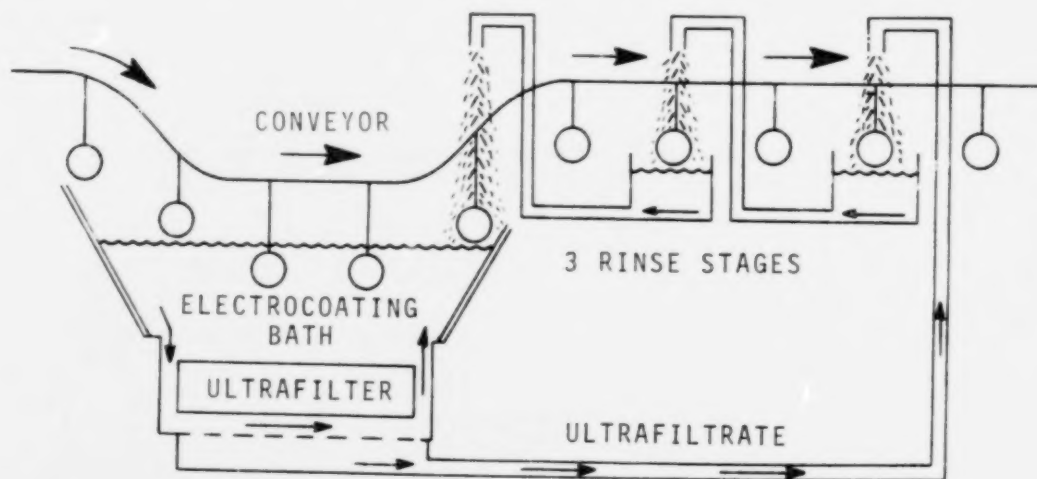


Figure 20. Electrocoating.

Theoretically, the electrocoating method should create no waste loads. In practice, however, some waste is unavoidable. It has been reported that the freshly deposited film contains from 0.07 to 2.0 wt% organic volatiles.³

³ Phillips, G. Electrocoat 71, paper No. 5, National Paint and Coating Association, Washington, D.C.

Using these weight percentages, and assuming a nonvolatile density of 1.44 kg/l (12 lb/gal), for each liter (gallon) of film coating 0.01 to 0.03 kg (0.08 to .12 lb) of organic volatile waste will be generated during the bake curing process. There is also a very minor amount of organic volatile waste caused by evaporation from the electrocoating tank, and a very small quantity of both organic volatiles and nonvolatile solids in ultrafiltrate waste water that may sometimes be discarded.

The electrocoat (Code 4Bw) paint compositions surveyed during this study and reported in Section 9 of this report list the weight OV associated with 1 unit volume of NV ranging from 0.31 to 0.47 kg/l (2.6 to 3.9 lb/gal). This is given as the ratio for the original fill of the electrocoating tank, and there are indications that replenishment paint, which must be continuously added to the tank, contains less OV, but detailed information is lacking.⁴

The "expected transfer efficiency" of the electrocoating method is better than 90% and is thought by some to be as high as 99%. Compared with the other methods discussed previously, the electrocoating method generates markedly less organic volatile and nonvolatile semisolid waste loads. There may also be a cost advantage in using the electrocoating method. In one case the cost has been described as "...equal to or even less than conventional dip coating methods...".⁵

POWDER COATINGS

The principle of the powder coating method is to apply a layer of fusible powdered plastics (powder paint) to the surface of the merchandise where it is melted and heat cured into a nonvolatile solid film coating. There are several techniques for applying the powder paint composition to the merchandise, each requiring a different arrangement of equipment.

Characteristics

Powder paint compositions have characteristic differences from liquid paint compositions. A bulk volume of liquid paint composition contains a specific volume percentage of nonvolatile solids, with the balance being volatile liquids. A bulk volume of powder paint composition contains only about 50 volume percent of nonvolatile solids, with the balance being air. Powder paint compositions "as bought" have a bulk volume density weight in the range of 0.6 to 0.84 kg/l (5 to 7 lb/gal), however, when the powder is melted into a nonvolatile solid, the solid density is in the range of 1.2 to 1.8 kg/l (10 to 15 lb/gal).

Fluidized Bed Technique

A "fluidized bed" is achieved by installing a false bottom made from a

⁴ Burnside, G. L., Brewer, G. E. F., Strosberg, G. G. Journal of Painting Technology, Vol. 41, No. 534, pp 431-437, July 1969.

⁵ Levinson, S. B. Journal of Painting Technology, pp 41-49, June 1972.

porous material inside the paint tank. A thin layer of powder paint is placed on top of the porous material. A controlled flow of air or an inert gas such as nitrogen is pumped into the tank chamber below the porous material. The turbulence caused as the air or gas passes through the porous material and out the top of the tank causes the particles of paint powder to rise and remain suspended much as dust particles in the air. The flow rate is controlled at a point where none of the particles are raised as high as the top of the tank (Figure 21).

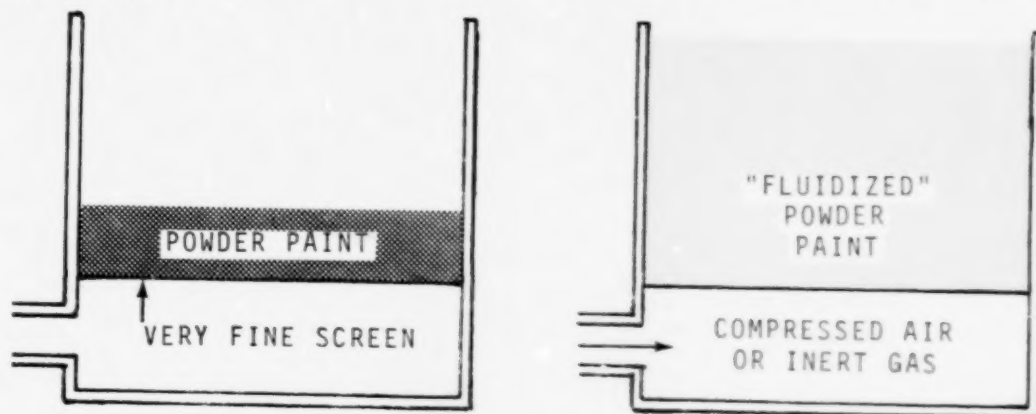


Figure 21. Fluidized bed dip tank.

The merchandise is preheated to a temperature above the melting point of the paint powder and then is dipped into the fluidized bed. The paint powder particles that contact the surface of the merchandise melt and form a film coating.

Fluidized Bed Plus Electrostatic Field Technique

A shallow "fluidized bed" is formed as described above, then the paint powder particles are charged by a high voltage electrostatic field (Figure 22).

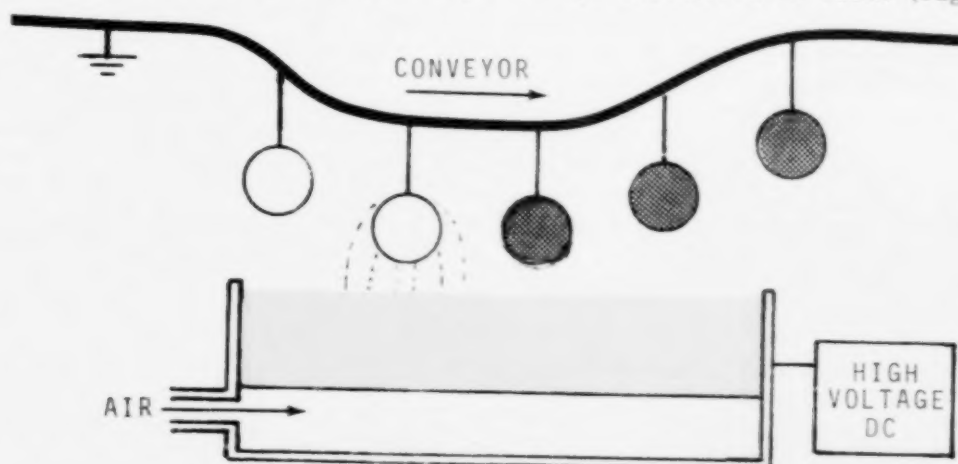


Figure 22. Electrostatic fluidized bed.

In this technique, the merchandise is not preheated but is electrically grounded to the power source that supplies the electrostatic field. The merchandise does not actually enter the fluidized bed, but when it passes above the surface the charged paint powder particles are attracted to it and form a coating of powder. The particles are retained on the surface of the merchandise by the residual electrostatic charge. The merchandise is then processed into a heating chamber where the paint powder particles melt and form a film coating.

Fluidized Spray Technique

The powder paint is fluidized by mixture with air or an inert gas such as nitrogen and sprayed from a paint gun under a very small pressure. The paint particles are charged by an electrostatic field at or near the point at which they leave the spray gun and the merchandise is grounded electrically to the power source that provides the field. The paint powder particles are attracted to the surface of the merchandise where they form a powder coating (Figure 23).

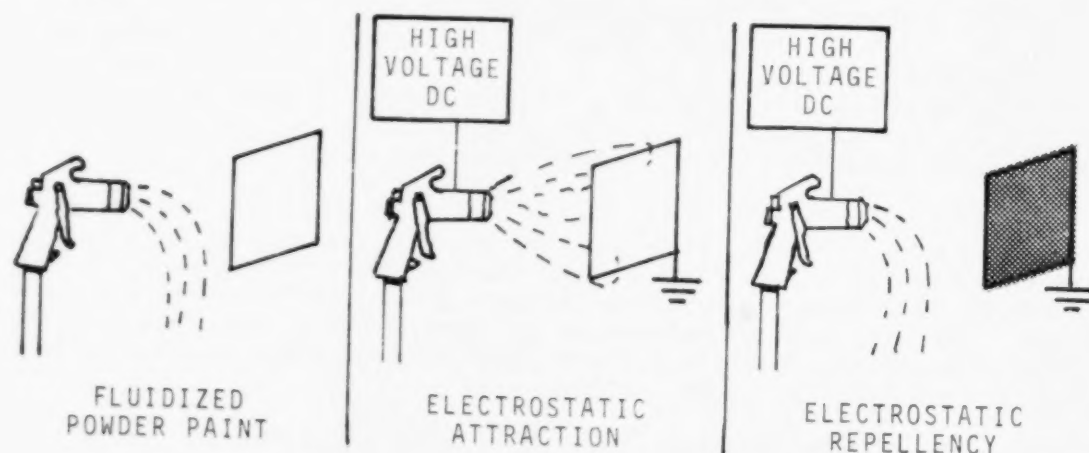


Figure 23. Fluidized electrostatic powder spraying.

The thickness of the powder coating on the merchandise can be predetermined and controlled by the strength of the electrostatic field. Due to the weight of the paint particles and the low pressure of the operation, without the electrostatic charge they would settle as they emerged from the paint gun. Even if they contacted the surface of the merchandise they would not be retained. When the powder coating has reached the desired thickness, the attraction is counteracted by the residual charge in the particles already attached and no more particles will be retained. This residual charge in the particles attached to the merchandise will also cause them to be retained on the surface while the merchandise is processed to a heat chamber where they melt and form a film coating.

Unlike liquid paint spraying, all the "overspray" in powder spraying operations is collected in a filter chamber and reused.

Summary

The "expected transfer efficiency" for powder paints using any of the techniques described above is very good, possibly as high as 98%.

The powder paints surveyed in this study and reported in Section 9 show a very favorably low generation of organic volatile waste loads. The weight of organic volatiles per unit volume of final nonvolatile film is in the range of 0.001 to 0.12 kg OV/1 NV (0.05 to 1.0 lb OV/gal NV). This is the result of coreactants in the paint powders.

There may also be a material cost savings in using powder paints. The coat has been described as "...equal to conventional films at equal film thickness...".⁶

PAINT LOSSES VS TRANSFER EFFICIENCY

It has been shown in the discussion of the various painting methods that some paint loss must be expected in the process of transferring a paint composition from the container to the surface of the merchandise. Losses will occur whether the most primitive or most sophisticated methods and equipment are used. These are called "unavoidable losses" in that they are inherent to the method and equipment used for the painting operation.

There are many factors which must be considered when determining the method and equipment to be used for a specific painting operation. Some factors, such as the quality of the finished film coating, may automatically eliminate the use of some classes of paint compositions and, therefore, some painting methods. The nature of the merchandise may also be a determining factor. For example, the roll coating method is obviously unsuited to merchandise with a highly irregular surface configuration.

When two or more painting methods are equally acceptable for a specific painting operation, the "unavoidable losses" associated with each method may become the deciding factor in the method selected.

The total amount of "unavoidable losses" represents the difference of the volume of nonvolatile solids in the paint used in the operation and the volume of nonvolatile solids in the film coating on the finished merchandise. For planning and calculation purposes this is usually expressed as "percent expected transfer efficiency" (% exp.t.e.).

However, a single distinct % exp.t.e. cannot be established for each painting method. "Unavoidable losses" for each method will vary with the peculiarities of the specific operation. For example, there are more overspray losses when painting small irregular pieces of merchandise than when painting large flat surfaces; there are more clean-up losses if the operation requires frequent changeover or shutdown; etc. Table 2 shows the range of % exp.t.e. found through the review of literature and/or received by direct communica-

⁶ Levinson, S. B., Journal of Painting Technology, pp 39-56, July 1972.

tion during the period of this study.

TABLE 2. EXPECTED TRANSFER EFFICIENCY

PAINTING METHOD	PERCENT EXPECTED TRANSFER EFFICIENCY
Air Atomized, Conventional	43% ¹ ; 50% ² ; 30-60% ³
Air Atomized, Electrostatic	87% ¹ ; 68-87% ⁴
Pressure Atomized, Conventional	65-70% ⁵
Pressure Atomized, Electrostatic	85-90% ⁶
Centrifugally Atomized, Electrostat.	93% ¹ ; 85-95% ⁴
Dip, Flow, and Curtain Coating	75-90% ⁶
Roll Coating	90-98% ⁶ ; 96-98% ⁷
Electrocoating	90-96% ⁶ ; 99% ²
Powder Coatings	50-80% ⁸ ; 98% ² ; 90-99% ⁹

¹ E. P. Miller, Ransburg Co.; SME Paper, FC73-553.

² J. A. Antonelli, duPont Co.; SME Paper, FC74-654.

³ J. A. Antonelli, duPont Co.; "depending upon equipment and shape of merchandise" (direct communication)

⁴ E. P. Miller, Ransburg Co.; "depending upon object being coated" (direct communication)

⁵ W. H. Cobbs, Jr., Nordson Corp.; (direct communication)

⁶ F. Scofield, Wapora, Inc.; EPA Contract 68-01-2656

⁷ M. Wismer, PPG Industries; (direct communication)

⁸ S. B. Levinson, D. Litter Lab.; Journal of Painting Technology pp 35-56, July 1972

⁹ T. W. Seitz, Sherwin-Williams Co.; "newer reuse methods" (direct communication)

WASTE LOADS VS TRANSFER EFFICIENCY

The following factors were established in Section 4:

- 1) All volatile components in paint compositions are sacrificed during the transfer and curing operations.
- 2) The quantity of paint composition required for a painting operation is determined by the volume of nonvolatile solids required in the film coating on the finished merchandise.

- 3) The greatest polluttional waste loads generated by painting operations are the organic volatile vapors emitted during transfer and curing.
- 4) The volume of waste loads does not provide meaningful data and must be converted to weight.

Assuming that a 100% transfer efficiency could be achieved, only volatile waste loads would be generated, and these would be in direct proportion to the ratio of the components in the "as used" paint composition. However, since 100% transfer efficiency is never realized, not only are volatile waste loads increased in proportion to the actual percentage of transfer efficiency, but nonvolatile waste loads are also generated.

A certain water borne spray paint (Code 1Aw 1) was shown in Section 4 to have a volume relationship of:

1.000 vol (liter or gallon) NV
0.568 vol (liter or gallon) OV
2.192 vol (liter or gallon) water
3.760 vol (liter or gallon) paint composition

If this paint composition is used in an operation with only a 50% transfer efficiency, only half the volume of NV would actually become film coating on the merchandise; the other half would become an NV waste load. The entire volume of OV would become an OV waste load.

TRANSFER EFFICIENCY CALCULATIONS

The weight of NV, OV, and total waste loads can be calculated by use of the following three equations.

Equation 5

The following equation may be used to calculate the weight of NV waste at any given "percent expected transfer efficiency":

$$wNV W_{et} = [(100/et) - 1] \times (A_p/K) \times t \times dNV$$

where

W	=	waste
et	=	percent expected transfer efficiency
A _p	=	area to be painted in m ² (ft ²)
K	=	1,000 m ² x 1 μm/l (1,604 ft ² x 1 mil/gal)
t	=	thickness of coating in μm (mil)

d = density in kg/l (lb/gal)

Example 5

To calculate the weight of the NV waste load generated by painting a surface area of 149 m² (1,604 ft²) with a film coating 25.4 μm (1 mil) thick at an expected transfer efficiency of 85% using a paint with an NV density of 1.75 kg/l (14.6 lb/gal):

$$\begin{aligned}w_{NV} W_{et} &= [(100/85) - 1] \times 149/1,000 \times 25.4 \times 1.75 \\&= (1.176 - 1) \times 0.149 \times 44.45 \\&= 0.176 \times 6.62 \\&= 1.17 \text{ kg NV waste expected}\end{aligned}$$

or, using U.S. standards

$$\begin{aligned}w_{NV} W_{et} &= [(100/85) - 1] \times 1,604/1,604 \times 1 \times 14.6 \\&= 0.176 \times 14.6 \\&= 2.57 \text{ lb NV waste expected}\end{aligned}$$

Equation 6

The following equation may be used to calculate the weight of OV waste at any given "percent expected transfer efficiency":

$$w_{OV} W_{et} = (100/et) \times (A_p/K) \times t \times w_{OV/vNV}$$

where

$$w_{OV/vNV} = \text{weigh (kg or lb) of OV per volume (l or gal) of NV}$$

Example 6

To calculate the weight of the OV waste load generated by the same painting operation used in example 5: (w_{OV/vNV} = 0.50 kg/l (4.3 lb/gal))

$$\begin{aligned}w_{OV} W_{et} &= (100/85) \times (149/1,000) \times 25.4 \times 0.52 \\&= 1.176 \times 0.149 \times 13.21 \\&= 2.31 \text{ kg OV waste expected or (5.06 lb)}\end{aligned}$$

Equation 7

The following equation may be used to calculate the weight of Total waste at any given "percent expected transfer efficiency":

$$wT W_{et} = wNV W_{et} + wOV W_{et}$$

where

$$T = \text{total}$$

Example 7

To calculate the weight of total waste loads generated by the operation described in Examples 5 and 6:

$$\begin{aligned} wT W_{et} &= 1.17 \text{ kg NV} + 2.31 \text{ kg OV} \\ &= 3.48 \text{ kg total waste} \quad (7.67 \text{ lb}) \end{aligned}$$

SUMMARY

Transfer efficiency has a direct relationship to all the waste loads generated by any painting operation. OV waste loads are generated by all painting operations and are directly proportional to the amount of OV in the total quantity of paint composition used in the painting operation. NV waste loads are the direct result of transfer efficiency; ideally, if a 100% transfer efficiency could be achieved, no NV waste loads would be generated, however, since this is nearly impossible, some NV waste loads are generated by all painting operations. NV waste loads rise at an accelerated rate with decreasing transfer efficiency.

Table 3 has been prepared to show the waste loads generated at various "percent expected transfer efficiency" for the specific painting operation

TABLE 3. WASTE LOADS VS PERCENT EXPECTED TRANSFER EFFICIENCY

% exp.e.t.	wOV W_{et}		wNV W_{et}		wT W_{et}		vOV + vNV	
	kg	(lb)	kg	(lb)	kg	(lb)	liter	(gal)
100	1.97	(4.34)	0.00	(0.00)	1.97	(4.34)	5.90	(1.56)
95	2.07	(4.56)	0.35	(0.77)	2.42	(5.33)	6.24	(1.65)
90	2.19	(4.83)	0.74	(1.63)	2.93	(6.46)	6.54	(1.73)
85	2.31	(5.09)	1.17	(2.57)	3.48	(7.67)	6.96	(1.84)
80	2.46	(5.42)	1.66	(3.66)	4.12	(9.08)	7.37	(1.95)
75	2.63	(5.79)	2.21	(4.87)	4.84	(10.66)	7.86	(2.08)
70	2.81	(6.19)	2.84	(6.26)	5.65	(12.45)	8.43	(2.23)
65	3.03	(6.68)	3.56	(7.84)	6.59	(14.52)	9.07	(2.40)
60	3.28	(7.23)	4.41	(9.72)	7.69	(16.95)	9.83	(2.60)
55	3.58	(7.89)	5.47	(12.05)	9.05	(19.95)	10.77	(2.85)
50	3.94	(8.68)	6.62	(14.58)	10.56	(23.26)	11.80	(3.12)
*33	5.91	(13.02)	13.28	(29.16)	19.19	(42.18)	17.70	(4.68)

* Used for the purpose of illustration only.

used in Examples 5, 6, and 7; i.e. to paint a surface area of 149 m (1,604 ft) with a film coating 25.4 μ m (1 mil) thick using paint composition Code 1Aw 1.

The information contained in Table 3 is shown graphically in Figure 24.

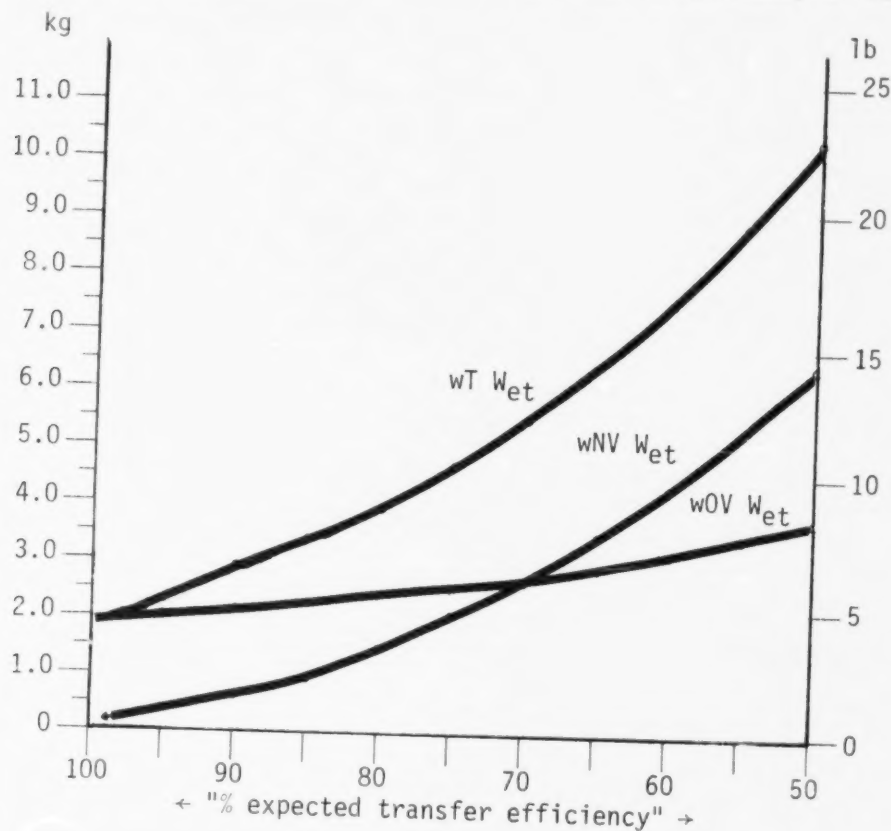


Figure 24. Waste loads vs percent expected transfer efficiency

The two most important factors to remember are:

- 1) OV waste loads are the result of both the ratio of OV to NV in the paint composition (wOV/vNV) and the expected transfer efficiency. Minimum waste loads are generated at maximum transfer efficiency and increase in direct proportion to the total volume of paint used.
- 2) NV waste loads are generated only as the result of transfer efficiency. Minimum waste loads are generated at maximum transfer efficiency and increase at an accelerating rate as percent of transfer efficiency decreases.

SECTION 6

PAINT CURING METHODS

The process by which the paint composition "as used" is transformed into a solid, wear-resistant nonvolatile film coating on the merchandise is known as "curing". Most paint compositions are formulated to function best when a specific curing method is used. However, some compositions may be used under several curing methods, or even with a combination of methods. Curing methods fall in the three general principles described below.

AMBIENT TEMPERATURE CURING

The simplest method of curing is provided by those paint compositions that "dry" in an atmosphere at or near the ambient temperature of the work area. There are three general classes of paint compositions that are normally cured at ambient temperature: 1) solvent and/or water borne paints that cure through evaporation of the liquid components; 2) paints which cure through the absorption of moisture from the atmosphere; and 3) two component paint compositions which, when mixed, solidify within a few minutes.

Evaporation

Air drying through evaporation was, historically, the earliest used method of paint curing. Paint compositions may undergo a strictly physical change as the solvents are evaporated, or they may undergo a combination of physical and chemical changes. Some paints, such as lacquers used for nail polish, cure by physical evaporation only. This is a reversible process, and the nonvolatile solid film can be redissolved into a liquid state by use of the same solvents.

Paint compositions with oils, such as linseed, as part of the liquid components cure by a combination of physical evaporation and chemical reaction. During the evaporation of the solvents, other components undergo a chemical combination with oxygen from the air. This is an irreversible process and the film cannot be redissolved.

Moisture Curing

Some paint compositions contain liquid components which when exposed to the air react with the moisture in the air to form solids. This is actually a combination of physical evaporation and chemical reaction during the curing process, and as such is irreversible. These paint compositions require special handling and must be kept sealed until they are used.

Two Component Paints

A comparatively new family of paints form polymerized films at ambient temperatures when two liquid components are mixed together. When the two components are mixed, they react chemically with each other to form a solid polymer. Since only a limited time is available to apply the paint after the two components are mixed, they are usually used in spray operations where they are mixed in the spray gun chamber.

BAKE CURING

The application of heat to accelerate the evaporation process is the most widely used curing method by industry. There are a number of ways to achieve "bake" curing, but they all function on the principle of subjecting the painted merchandise to temperature in the range of 120 to 175°C (250 to 350°F) for a period usually about 8 to 30 minutes. Continuous air circulation through the baking chamber is essential to remove the organic volatile waste and to dilute the vapors to below the explosive level.

RADIATION CURING

There are several classes of liquid paint compositions that will solidify quite rapidly when exposed to radiant energy. The two classes surveyed in this study were the electron beam activated and the ultra-violet ray activated.

Electronic Beam Curing

Electronic beam radiation curable paint compositions are identified as Code 6eb in Section 9. These paints may be applied to the merchandise by a variety of methods such as spray, roll, flow, dip, etc. After the paint is applied the merchandise is placed in a chamber containing a relatively oxygen free atmosphere (usually less than 500 ppm) and exposed to high energy electron beams (β -rays). When the beta-rays impinge on the liquid paint components, a chemical reaction is initiated which causes them to solidify into a solid film coating (Figure 25).

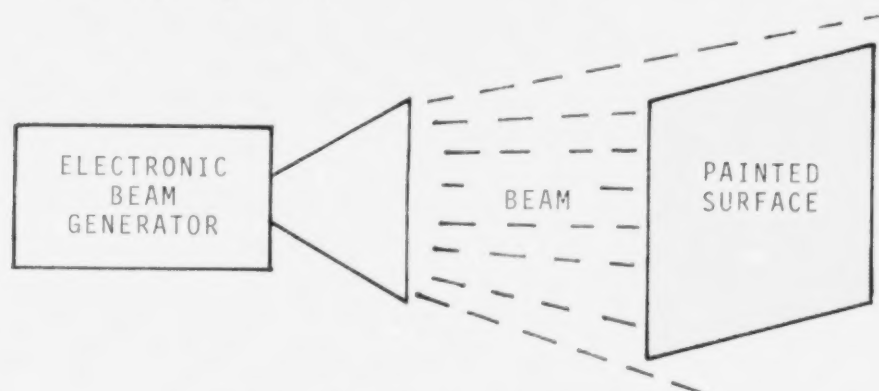


Figure 25. Electron beam curing.

Paints in this class are used where a comparatively thick film coating is required on either flat or profiled merchandise. The composition may be either pigmented or clear. The weight of organic volatiles associated with a unit volume of final solid nonvolatile film is approximately 0.048 kg OV/1 NV (0.40 lb OV/gal NV).

In comparison with other classes of paints, electron beam curing paints have been reported as competitive: "...cost of liquid coating mil x ft² may be less than that of solvent thinned coatings...".⁷

Ultra-Violet Ray Curing

Ultra-violet ray curable paint compositions are identified as Code 6uv in Section 9. These paint compositions are used where a comparatively thin film coating is required on virtually flat surfaces, therefore, they are generally applied to the merchandise by the roll coating method. The freshly coated merchandise is then passed within a few inches of one or more ultra-violet lamps (usually mercury vapor tubes) which emit 315 to 400 millimicron waves (Figure 26).

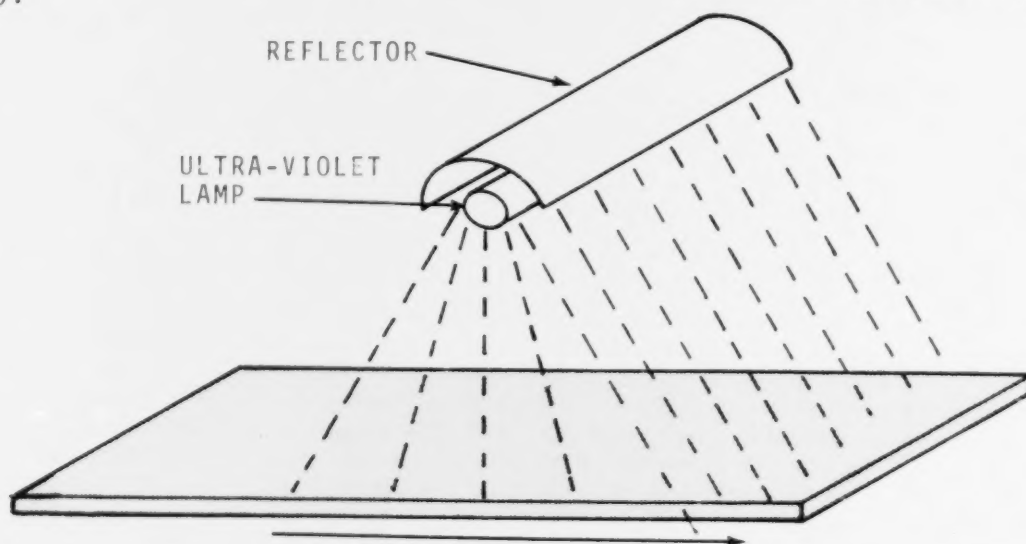


Figure 26. Ultra-violet ray curing

The weight of organic volatiles associated with a unit volume of final solid nonvolatile film ranges from 0.024 to 0.060 kg OV/1 NV (0.20 to 0.50 lb OV/gal NV).

Ultra-violet ray curing paint compositions have been described as having: "...limited applicability: thin films and special pigments...low capital cost...less floor space...".⁷

⁷ Levinson, S. B. Journal of Painting Technology, pp 29-40, August 1972.

FORMATION OF COREACTANTS

In addition to the organic volatile wastes previously discussed, there are certain organic volatiles generated by chemical reaction during the curing process of some paint compounds. These organic volatiles are called "coreactants (COR)". The coreactants most frequently encountered are water, methanol, etc. The weight of coreactants has been reported as usually less than 5 wt% of the nonvolatile solids portion of the paint compositions.⁸

The weight of vaporized, organic volatile coreactants has not been included in the previous calculations of weight OV/volume NV. (An exception has been made for the powder paints surveyed in Section 9. The weight of coreactants has been included in the tables in Section 9 for powder paints (Code 5B) as these are the only organic volatile wastes for these compositions.)

Prior to the chemical reaction that causes them to vaporize, coreactants are actually a part of the nonvolatile solids in the paint composition.

Equation 8

The following equation may be used to calculate the weight of coreactants generated during the curing process. The weight of organic volatile coreactant waste must then be added to the organic volatile waste calculated by other considerations.

$$wCOR = (A_p/K) \times t \times dNV \times (wt\% COR/100)$$

where

$$A_p = \text{area painted}$$

$$K = 1,000 \text{ m}^2 \times 1 \mu\text{m} \quad (1,604 \text{ ft}^2 \times 1 \text{ mil})$$

$$t = \text{thickness of nonvolatile film coating}$$

$$dNV = \text{density of nonvolatiles}$$

$$wt\% COR = \text{weight percentage of coreactants in nonvolatiles}$$

Example 8

To calculate the wCOR generated during the curing of a painted surface area of 149 m² (1,604 ft²) with a film thickness of 25.4 μm (1 mil) assuming a dNV of 1.98 kg/l NV (16.5 lb/gal NV) and a wt% COR of 4.5:

$$\begin{aligned} wCOR &= (149/1,000) \times 25.4 \times 1.98 \times (4.5/100) \\ &= 0.34 \text{ kg} \quad (0.74 \text{ lb}) \end{aligned}$$

⁸ Greer, S. T.; and Anderson, C.; Industrial Finishing, April 1973. (and direct communications with the authors and others)

Odors

Heavy malodorous fumes have been detected at times during the curing process of some paint compositions. These fumes are currently the subject of odor analysis and further study.⁹

⁹ Schuetzle, D.; Prater, T. J.; and Ruddell, S. R.; "Sampling and Analysis of Emissions from Stationary Sources: I. Odor and Total Hydrocarbons", Journal of the Air Pollution Control Association, Volume 25, Page 925, (1975)

SECTION 7

SANDING AND STRIPPING

There are certain unavoidable losses of paint solids that are caused by the nature of the painting operation and in some cases by mistakes made in the operation. Primary among these are the losses caused by sanding operations between coats and stripping necessary to remove defective coats.

SANDING

Sanding may be necessary to achieve the desired smoothness to the surface of the film coating on the merchandise. Cured film coatings may show some imperfections due to defects in the original surface of the merchandise, by the settling of dust or lint on the paint before it dries, and some roughness or "orange peel" effect inherent in the paint or painting technique. These imperfections are removed by either a wet or dry sanding process, which removes part of the film coating and generates a small amount of nonvolatile waste (Figure 27).

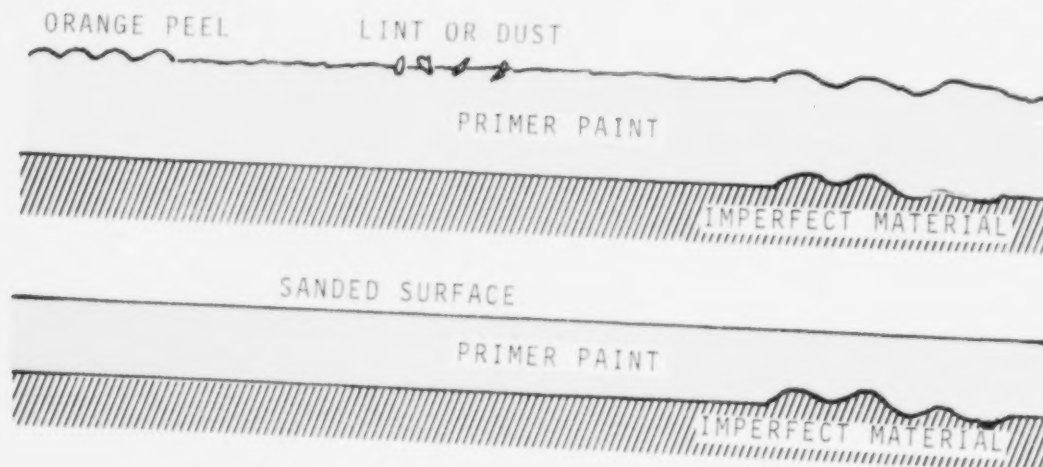


Figure 27. Sanding painted surfaces.

Merchandise with a highly uneven or porous surface is often painted first with a primer coat and sanded smooth before the application of the finished coatings. Calculation of the waste loads generated by sanding operations is extremely difficult. Actually, the waste should include the weight of the discarded disks or belts of sandpaper, and in the case of a wet sanding process,

the total weight of the detergents, oils, or organic solvents used.

STRIPPING

Occasionally the film coating applied to some pieces of merchandise may be defective or may be damaged to a point where it must be removed. In many painting processes, paint may also accumulate on equipment used in the process that must be stripped.

A paint "stripping" operation usually consists of a stripping bath into which the parts to be stripped are submerged. The stripping bath is composed of water and paint-lifting chemicals, usually caustic soda, surfacants, melted salts, etc. The bath is usually heated to near the boiling point. The process may include scraping or wire brushing and two or more emersions may be necessary.

The weight of paint stripped is usually relatively small in comparison to the total paint consumption in the overall operation, except in refinishing shops where it may be a normal part of the operation.

Equation 9

The following equation may be used to calculate the weight of stripped paint:

$$wW_s = (dNV/K) \times [(A_m \times t_m) + (A_h \times t_h)]$$

where

wW_s = weight of stripped off waste

A_m = area of merchandise stripped

t_m = thickness of film on merchandise

A_h = area of hangers stripped

t_h = thickness of film on hangers

Example 9

To calculate the wW_s generated by a stripping operation consisting of a merchandise area of 12.9 m^2 (138.9 ft^2) with a film thickness of $50.8 \text{ } \mu\text{m}$ (2 mil) and a hanger area of 1.35 m^2 (14.5 ft^2) with a film thickness of $557.2 \text{ } \mu\text{m}$ (18 mil) assuming a dNV of 2.02 kg/l (16.83 lb/gal):

$$\begin{aligned} wW_s &= (2.02/1.0) \times [(166.4 \times 0.000508) + (1.82 \times 0.0005572)] \\ &= 2.02 \times (0.0085 + 0.001) \\ &= 0.019 \text{ kg} \quad (.158 \text{ lbs}) \end{aligned}$$

Summary

It should be noted that the thickness of the film coating on the merchandise is usually only about 25.4 to 76.2 μm (1 to 3 mils), while the thickness of the film on the hangers may be 500 μm (20 mils) or more. It should also be noted that the nonvolatile paint solids are degraded by stripping into volatile and/or dispersed liquids.

While the weight of nonvolatile paint solids that are stripped is usually relatively small, the weight of the stripping chemicals may present quite a sizable waste load. The total waste load generated by the stripping operation must be determined or estimated and added as part of the overall waste load of the painting operation.

SECTION 8

CALCULATION OF WASTE LOADS

GENERAL

It has been shown in the preceding Sections of this report that both organic volatile (OV) and nonvolatile (NV) waste loads are generated by all painting operations. Procedures and equations have been given for the prediction of waste loads based on known factors.

The actual waste loads generated can be determined based on these same known factors plus production and inventory data developed during the period of operation.

PREDICTION OF WASTE LOADS

Equations 1 through 9 were developed and have been presented as tools to be used for the calculation of predicted waste loads from a specific, planned painting operation. Actually, equations 1 through 4 are used for basic painting calculations and equations 5 through 9 are used for waste load calculations.

Each calculation requires the use of known or estimated factors. For example:

- 1) The surface area of the merchandise to be painted.
- 2) The thickness of the film coating to be applied.
- 3) Percent of expected transfer efficiency of the painting method and equipment to be used.
- 4) The nature of the components of the paint composition to be used. (Specifically the density weight of the nonvolatile components per volume unit and the weight of organic volatile components per volume unit of nonvolatiles.)
- 5) If applicable, the weight percent of coreactants in the nonvolatiles.

Using the above factors and equations 5, 6, and 8, the predicted NV, OV, and COR waste loads can be calculated.

Additional waste loads are occasionally generated by paint losses result-

ing from accidental spills and leaks, cleaning and repairing of equipment, the use of organic volatile cleaning materials, and paint sanding and stripping operations. Though these waste generations usually evade prediction, it is estimated that in most painting operations they actually add less than 5 percent to the predictable waste loads.

DETERMINATION OF WASTE LOADS

The actual waste loads generated during a painting operation include all organic volatile and nonvolatile solids which are consumed during the operation except the weight of the nonvolatile solids that actually leave the plant in the form of the finished film coating on the merchandise.

In addition to the five basic factors required to calculate the predicted waste loads, the following factors are required to calculate the determined waste loads:

- 1) The total consumption of paint compositions, thinners, cleaning fluids, etc. during a specific production or inventory period.
- 2) The total area and thickness of the nonvolatile film coating on the merchandise that actually leaves the facility.

Using all this data, the weight of nonvolatile waste (wNV W), the weight of organic volatile waste (wOV W), and the weight of total waste (wT W) can be determined by calculations using Equations 10, 11, and 12.

Equation 10

The following equation may be used to calculate the determined nonvolatile waste load generated by a specific painting operation:

$$wNV W_{det} = wNV_{cons} - [(A_p/K) \times t \times dNV]$$

where

W_{det} = determined waste load

wNV_{cons} = weight of the nonvolatile components of all paint composition consumed during the painting operation

As you can see, this equation is quite similar to equation 5 except that actual consumption data is used in place of an "expected transfer efficiency" factor. The determined NV waste load will include all losses of nonvolatile solids caused by transfer efficiencies, sanding and stripping processes, clean-up, spillage, etc. However, NV wastes from sources other than the paint composition, such as discarded sand paper or abrasives used in sanding operations are not included. It is estimated that NV waste from such sources will add only a very small percentage to the plant waste load, and in many cases may be entirely insignificant. If such wastes are considered significant, they must be added separately.

Example 10

To calculate the weight of the determined NV waste load generated by an operation in which 9,290 m² of essentially flat merchandise has been painted with a nonvolatile film coating 30.5 µm thick. Assume that inventory records show that 863 liters (228.4 gallons) of paint composition Code 1Bs 2 containing 412 kilograms (908 pounds) of NV with a density of 1.15 kg/l (9.6 lb/gal) were consumed during the operation:

$$\begin{aligned}wNV W_{det} &= 412 - [(9,290/1,000) \times 30.5 \times 1.15] \\&= 412 - (9.29 \times 35.08) \\&= 412 - 325.89 \\&= 86.11 \text{ kg} \quad (189.7 \text{ lbs})\end{aligned}$$

The above example shows only the determined waste load generated by the NV solids in the paint composition used. If significant additional waste is generated by other sources such as discarded sand paper or abrasives used in sanding or stripping operations, that weight must be added to the above total.

Equation 11

The following equation may be used to calculate the determined organic volatile waste load generated by a specific painting operation:

$$wOV W_{det} = vNV_{cons} \times wOV/vNV$$

where

$$W_{det} = \text{determined waste load}$$

$$vNV_{cons} = \text{volume of the nonvolatile components of all paint composition consumed during the painting operation}$$

$$wOV/vNV = \text{weight of OV per unit volume of NV}$$

This equation produces a result similar to equation 6 by using actual consumption data rather than "expected transfer efficiency" and finished film coating data. The determined OV waste load will include all wastes generated by the organic volatiles in the paint composition as used. However, OV wastes from sources other than the paint composition, such as organic volatile cleaning fluids, chemicals used for paint stripping, etc., are not included. This additional OV waste in most painting operations represents only a small percentage of the plant waste load, but in some cases may be quite significant. If such wastes are considered significant, they must be added separately.

Example 11

To calculate the weight of the determined OV waste load generated by the same painting operation used in Example 11: (The weight ration of OV to unit

volume of NV for paint composition Code 1Bs 2 as used is 1.28 kg/liter (10.7 lb/gal.)

$$\begin{aligned}wOV W_{det} &= 863 \times 1.28 \\ &= 1104.6 \text{ kg} \quad (2444 \text{ lbs})\end{aligned}$$

The above example shows only the determined waste load generated by the organic volatile solvents in the paint composition used. If significant additional waste is generated by other sources such as cleaning fluids or stripping compounds, that weight must be added to the above total.

Equation 12

The following equation may be used to calculate the determined total waste loads generated by a specific painting operation:

$$wT W_{det} = wNV W_{det} = wOV W_{det} \times wCOR$$

where

$$wT W_{det} = \text{weight of the total determined waste loads}$$

$$wNV W_{det} = \text{result of equation 10 with any other significant NV waste added}$$

$$wOV W_{det} = \text{result of equation 11 with any other significant OV waste added}$$

$$wCOR = \text{result of equation 8}$$

The weight of coreactant waste as calculated by use of equation 8 is based on the volume of NV applied as a film coating on the merchandise. This factor is used for two primary reasons: 1) Coreactants are most often found in paint compositions designed for bake or radiation curing; and 2) the release of coreactant waste is stimulated by the curing process.

Actually, since coreactant waste is the result of chemical reaction which transform a percentage of the nonvolatile paint solids into volatile coreactants, for a finite calculation of waste loads the weight of coreactant waste should be subtracted from the weight of NV waste as determined. In fact, coreactant waste may be generated by the entire weight of NV consumed, though coreactants released from NV waste may be much slower than that released from the NV film on the merchandise during the curing operation.

Example 12

To calculate the weight of the determined total waste loads generated by a painting operation in which 9,290 m² of essentially flat merchandise has been prime coated with a film coating 20.3 µm thick and top coated with a film coating 35.6 µm thick. Assume that inventory records show that 277 liters (73.4 gallons) of paint composition Code 4Bw 4 containing 295 kilograms (650 pounds)

of NV with a density of 1.43 kg/l (11.9 lb/gal) were consumed during the prime coating operation and that 969 liters (256.4 gallons) of paint composition Code 1Bs 3 containing 704 kilograms (1,551 pounds) of NV with a density of 1.58 kg/l (13.2 lb/gal) were consumed during the top coating operation: (Primer paint composition Code 4Bw 4 contains no coreactants; top coat paint composition Code 1Bs 3 contains approximately 4 wt%.)

Prime Coat--

$$\begin{aligned}
 wNV W_{det} &= 295 - [(9,290/1,000) \times 20.3 \times 1.43] \\
 &= 295 - (9.29 \times 29.03) \\
 &= 295 - 270 \\
 &= 25 \text{ kg NV waste determined} \quad (56 \text{ lb}) \\
 wOV W_{det} &= 0.31 \times 206 \\
 &= 64 \text{ kg OV waste determined} \quad (142 \text{ lb}) \\
 wT W_{det} &= 25 + 64 + 0 \\
 &= 89 \text{ kg Total waste determined} \quad (198 \text{ lb})
 \end{aligned}$$

Top Coat--

$$\begin{aligned}
 wNV W_{det} &= 704 - [(9,290/1,000) \times 35.6 \times 1.58] \\
 &= 704 - (9.29 \times 56.25) \\
 &= 704 - 523 \\
 &= 181 \text{ kg NV waste determined} \quad (399 \text{ lb}) \\
 wOV W_{det} &= 1.06 \times 446 \\
 &= 473 \text{ kg NV waste determined} \quad (1,042 \text{ lb}) \\
 wCOR &= (9,290/1,000) \times 35.6 \times 1.58 \times (4/100) \\
 &= 9.29 \times 56.25 \times 0.04 \\
 &= 21 \text{ kg COR waste determined} \quad (46 \text{ lb}) \\
 wT W_{det} &= 181 + 473 + 21 \\
 &= 675 \text{ kg Total waste determined} \quad (1,487 \text{ lb})
 \end{aligned}$$

Total Plant Waste--

The total plant waste for this specific painting operation can be found by adding the sum of the prime coat total waste to the sum of the top coat

waste:

$$\text{Total Plant Waste} = 89 + 675$$

$$= 764 \text{ kg Total Plant waste determined (1,683 lb)}$$

PREDICTED VS DETERMINED WASTE LOADS

For a comparison of the predicted and determined waste loads for the operation described in example 12, first calculate the predicted loads using the highest "expected transfer efficiency" for the painting method used in accordance with equations 5 and 6:

Prime Coat (Electrocoating method at 96% expected transfer efficiency)

$$w_{NV} W_{et} = [(100/96) - 1] \times (9,290/1,000) \times 20.3 \times 1.43$$

$$= 0.042 \times 9.29 \times 29.03$$

$$= 11.33 \text{ kg NV waste predicted (25 lb)}$$

$$w_{OV} W_{et} = (100/96) \times (9,290/1,000) \times 20.3 \times 0.31$$

$$= 1.042 \times 9.29 \times 6.3$$

$$= 61 \text{ kg OV waste predicted (134.4 lb)}$$

Top Coat (Air atomized spray method at 87% expected transfer efficiency)

$$w_{NV} W_{et} = [(100/87) - 1] \times (9,290/1,000) \times 35.6 \times 1.58$$

$$= 0.149 \times 9.29 \times 56.25$$

$$= 77.8 \text{ kg NV waste predicted (171.4 lb)}$$

$$w_{OV} W_{et} = (100/87) \times (9,290/1,000) \times 35.6 \times 1.06$$

$$= 1.149 \times 9.29 \times 37.74$$

$$= 402.85 \text{ kg OV waste predicted (887.5 lb)}$$

As you can see, the predicted loads at these transfer efficiencies are less than the determined loads calculated in example 12. Next, calculate the predicted loads using the lowest "expected transfer efficiency":

Prime Coat (At 90% expected transfer efficiency)

$$w_{NV} W_{et} = [(100/90) - 1] \times (9,290/1,000) \times 20.3 \times 1.43$$

$$= 0.111 \times 9.29 \times 29.03$$

$$= 29.94 \text{ kg NV waste predicted } (66 \text{ lb})$$

$$wOV W_{et} = (100/90) \times (9,290/1,000) \times 20.3 \times 0.31$$

$$= 1.111 \times 9.29 \times 6.3$$

$$= 65 \text{ kg OV waste predicted } (143.2 \text{ lb})$$

Top Coat (At 68% expected transfer efficiency)

$$wNV W_{et} = [(100/68) - 1] \times (9,290/1,000) \times 35.6 \times 1.58$$

$$= .47 \times 9.29 \times 56.25$$

$$= 245.6 \text{ kg NV waste predicted } (541 \text{ lb})$$

$$wOV W_{et} = (100/68) \times (9,290/1,000) \times 35.6 \times 1.06$$

$$= 1.47 \times 9.29 \times 37.74$$

$$= 515.4 \text{ kg OV waste predicted } (1,135.4 \text{ lb})$$

Using the lower transfer efficiencies, the predicted waste loads are greater than the determined loads calculated in example 12. Therefore, the determined waste loads are within the acceptable percentage of transfer efficiency range.

SECTION 9

COMMERCIAL PAINT COMPOSITIONS SURVEYED

GENERAL

During the course of this study, a number of commercial paint compositions currently available on the market were surveyed. Such paint compositions are usually classified generically according to the filmformer content. The filmformers contained in the surveyed paints included: acrylic, alkyd, epoxy, phenolic, cellulose acetate butyrate, polyester, polythioester, urethane, and vinyl.

The filmformers constitute the majority of the nonvolatile solids in most paint compositions, with pigments and other additives constituting the rest.

The greatest and most troublesome waste loads are generated by the organic volatile solvents used in the paint compositions. Most paint compositions are carefully formulated for compatibility with specific painting methods and equipment and curing processes. For example, compositions containing acrylic filmformers may be designed for application by spray, dip, roll etc. methods. Dip coating requires less organic volatile solvents than spray coating, and roll coating requires still less. Also, solvent borne paint compositions are more suitable for air drying, and water borne more suitable for bake drying.

It is obvious from the above that the organic volatile solvent content of paint compositions is influenced by the paint method and equipment and curing process for which it was designed. Furthermore, it has been established in the earlier Sections of this report that the normal unavoidable losses of nonvolatile paint solids during painting operations are also directly related to these two factors.

This study has identified the following causes for waste generation and paint losses during industrial painting operations:

- 1) All volatile components of paint compositions are sacrificed during the transfer and curing processes and result in waste load generation.
- 2) Some loss of nonvolatile solids are inherent in all painting methods and equipment which result in nonvolatile waste load generation.
- 3) Sanding and stripping operations cause paint losses and contribute to nonvolatile waste load generation.
- 4) Cleaning and repair of equipment cause paint losses and contribute to both organic volatile and nonvolatile waste load generation.

- 5) Coreactants generated by chemical reaction during the curing process of some paint compositions cause the loss of nonvolatile paint solids and contributes to waste load generation.
- 6) Some losses will occur from accidental spillage and leakage.

CLASSIFICATION OF PAINT COMPOSITIONS

Early in the survey of available commercial paint compositions it was deemed advisable to classify the surveyed paints in accordance with the painting method and curing process for which they were designed, and to assign codes to each class to facilitate cross reference. The first step was to assign each paint surveyed to one of the following general numeric classes:

- 1 Spray coatings
- 2 Dip, Flow and Curtain coatings
- 3 Coil and Roll coatings
- 4 Electro coatings
- 5 Powder coatings
- 6 Radiation Cured coatings
- 7 High Solids Spray coatings
- 8 Low Solvent Emulsion coatings
- 9 Powder Slurry coatings

During the survey, attention was particularly drawn to the last three classes of paints identified above due to their relatively low organic volatile content and resulting low generation of OV waste loads. These paints are comparatively new and are not presently in generally wide usage. These new paint compositions have been developed by resin and paint manufacturers largely to meet environmental requirements for low OV waste generation.

It was found that in many of the paint classes some of the compositions were designed for air drying and others for bake curing. The capital letters A and B were assigned to these compositions respectively to identify the curing process. For class 6, Radiation Cured coatings, it was found that some compositions were designed for electron beam curing and others for ultraviolet light curing. The lower case letters eb and uv were assigned to these compositions respectively to identify the type of radiation that is required.

Finally, it was found that in many of the paint classes, some of the compositions contain only organic volatile solvents as liquid components while others contain primarily water. These compositions are commonly referred to as solvent borne and water borne. The lowercase letters s and w were assigned to these compositions to identify the primary liquid component.

Also, since more than one commercial paint composition was surveyed within some of the paint classes and having the same characteristics, a serial number was assigned to each composition surveyed. Thus, the first surveyed Spray paint, designed for Air drying, solvent borne, was assigned a Code 1As1.

WASTE LOAD COMPUTATION DATA

The computation of either predicted or determined waste loads requires the use of basic data related to the paint composition used in the painting operation. The two basic factors required to use the equations given in the previous sections of this report are: 1) the density of the nonvolatile components (dNV); and 2) the weight of organic volatiles associated with a volume unit of nonvolatiles (wOV/vNV).

These data are usually obtained in one of the following ways:

- 1) Directly from the manufacturer of the paint composition. This is by far the easiest course, and will be provided by most manufacturers in immediately usable form in response to communications if they understand the purpose for which it is requested.
- 2) By using formulation data provided in the manufacturer's literature. This process requires the mathematical computations necessary to develop the desired information.
- 3) By laboratory determination of a quantity of the paint composition. Such analysis should be conducted in accordance with the ASTM Paint Testing Manual, Philadelphia, Pa.

COMPUTATIONS USING MANUFACTURER'S LITERATURE

The following illustrates the computations necessary to develop the density of NV components (dNV) and weight of OV associated with a volume of NV (wOV/vNV) from typical information provided in the manufacturer's literature.

Typical Manufacturer's Data

The following is the data supplied in manufacturer's literature for paint composition Code 1Aw 1. This composition is an air drying, water borne, short oil alkyd white enamel, designed for use in spray painting operations "as bought" without the addition of thinners, based on Aroclon 363 resin binder (Formula 8042-50-29b), ADM Formulary No. P-216.

ADM Formulary No. P-216

<u>Component</u>	<u>Weight</u>		<u>Volume</u>	
	<u>lb</u>	<u>kg*</u>	<u>gal.</u>	<u>lit.*</u>
Rutile TiO ₂	170.0	77.2	4.86	18.4
Aroclon 363 Resin	102.0	46.3	11.65	44.0
Naptha	3.4	1.5	0.52	2.0
Water	68.0	30.9	8.35	31.5

<u>Component</u>	<u>Weight</u>		<u>Volume</u>	
	<u>lb</u>	<u>kg*</u>	<u>gal.</u>	<u>lit.*</u>
Pebble Mill Grind-24 ^h				
Arolon 363 Resin	323.0	146.6	36.87	139.4
24% Lead Naphthenate Drier	0.4	0.2	0.04	0.15
6% Cobalt Naphthenate Drier	1.8	0.8	0.22	0.83
Water	307.0	139.4	37.49	141.71
TOTALS	975.6	442.9	100.00	377.99

* Weight and volume were given by the manufacturer in U.S. measures; metric measures added by the author.

Formula 8042-50-29b

	<u>Density</u>	
	<u>lb/gal</u>	<u>kg/l</u>
Arolon 363	8.76	1.052
50 wt% NV	9.89	1.188
25 wt% OV	7.50	0.901
25 wt% H ₂ O	8.20	0.985

Computations

Using the above manufacturer's data, the following computations must be made before dNV and wOV/vNV can be calculated;

Arolon 363--

$$\begin{aligned}
 \text{Vol\% NV} &= [(\text{density Arolon 363} \times 0.5) / \text{dNV}] \times 100 \\
 &= [(8.76 \times 0.5) / 9.89] \times 100 \\
 &= (4.38 / 9.89) \times 100 \\
 &= 44.2
 \end{aligned}$$

ADM Formulary No. P-216--

<u>Component</u>	<u>Weight OV</u>		<u>Volume NV</u>	
	<u>lb</u>	<u>kg</u>	<u>gal.</u>	<u>lit.</u>
Rutile TiO ₂			4.86	18.4

<u>Component</u>	<u>Weight OV</u>		<u>Volume NV</u>	
	<u>lb</u>	<u>kg</u>	<u>gal.</u>	<u>lit.</u>
Arolon 363 Resin	25.5	11.6	5.15	19.5
Naptha	3.4	1.5		
Arolon 363 Resin	80.8	36.7	16.30	61.6
24% Lead Naphthenate Drier	0.399	0.199	0.001	0.001
6% Cobalt Naphthenate Drier	1.799	0.799	0.001	0.001
TOTALS	111.9	50.8	26.3	99.5

As you can see, all the water component has been dropped from the above computation. The driers add an insignificant volume of coreactant solids to the total volume of NV which is actually even less than the 0.001 shown. The estimated wCOR generated by use of this paint composition is less than 0.05% of total NV weight so is seldom worth the effort to calculate.

Total Weight of NV--

$$\begin{aligned}
 wNV &= w \text{ Rutile} + (w \text{ Arolon 363} \times \text{wt\% NV}) \\
 &= 170 + (425 \times 0.5) \\
 &= 382.5 \text{ lb} \quad (173.6 \text{ kg})
 \end{aligned}$$

Density of NV--

$$\begin{aligned}
 dNV &= wNV/vNV \\
 &= 382.5/26.3 \quad (173.6/99.5) \\
 &= 14.5 \text{ lb/gal} \quad (1.75 \text{ kg/l})
 \end{aligned}$$

Weight of OV Associated With 1 Unit Volume of NV--

$$\begin{aligned}
 wOV/vNV &= 111.9 \text{ lb OV}/26.3 \text{ gal NV} \quad (50.8 \text{ kg OV}/99.5 \text{ l NV}) \\
 &= 4.26 \text{ lb OV/gal NV} \quad (0.51 \text{ kg OV/l NV})
 \end{aligned}$$

Similar computations were performed for each paint composition surveyed during the study and the resulting dNV and wOV/vNV data has been entered in the appropriate columns in Table 4. (In a few cases, manufacturer's data was not available, hence computations were not possible and Unk has been entered on the Table.) Table 5 is a summary showing the range of dNV and wOV/vNV within each class of paint compositions surveyed.

TABLE 4. CLASSIFICATION AND COMPOSITION OF PAINTS SURVEYED

PAINT CLASS	PAINT DESCRIPTION (FORMULATION)	COMPOSITION OF BINDER	SUGGESTED USE	NV kg/lit (lb/gal)		kg OV/lit NV (lb OV/gal NV)	
						buy	use
1As - SPRAY, Air drying, solvent borne	1. Medium Oil Alkyd White Enamel (Ashland P-31)	52% Soybean Oil, 34% Phth. Anh. in Aliphatics (Aroplaz 1082M60)	TTR266d - Type IV, low vis., color fast	1.50 (12.5)		2.09 (17.4)	2.09 (17.4)
	2. Modified Alkyd Red Primer (Ashland Q-405a)	32% Linseed/Tung Oil, 39% Phth. Anh. in Xylene - Modifier: Phenolic resin (Aroplaz X663X50)	TTE315 & TTP664c fast dry, lift resist.	1.90 (15.8)		1.09 (9.10)	1.39 (11.6)
	3. Modified Alkyd Brown Primer (Ashland Q-315a)	32% Linseed/Tung Oil, 39% Phth. Anh. in Xylene - Modifier: Phenolic resin (Aroplaz X663X50)	Rust inhibiting, lacq. resisting	2.21 (18.4)		1.39 (11.6)	1.39 (11.6)
	4. Modified Alkyd Green Primer (Ashland P-111)	29% Linseed Oil, 30% Phth. Anh. in VM & P - Modifier: Rosin (Aroplaz 1365V50)	Fast drying, lt. color, drums, machinery, etc.	1.70 (14.2)		1.69 (14.1)	1.69 (14.1)
	5. Urethane Lacquer Blue (Ashland R-501)	25% Urethane in Xylene/MIBK/but. 20/30/30 (Arothane M529)	For flexing parts like bumpers, etc.	1.69 (14.0)		3.37 (28.1)	4.45 (37.1)
	6. Short Oil Alkyd White Enamel (Ashland P-49)	30% Tall Oil, 40% Phth. Anh. in Xylene (Aroplaz 6065X50)	Fast drying, economical, industrial finish	1.73 (14.4)		1.50 (12.5)	2.12 (17.7)
	7. Medium Oil Alkyd White Gloss Enamel (Ashland I-46)	51% Soybean Oil, 30% Phth. Anh. in mineral spirits	High viscosity, general purpose, flexible, hard	1.61 (13.4)		1.24 (10.3)	1.78 (14.8)
	8. Zinc Rich Primer (Mirasol 601)	Epoxyester Xylene, naphtha/acetate	Industrial weld-through primer	3.82 (31.8)		1.10 (9.20)	Unk Unk
1Aw - SPRAY, Air drying, water borne	1. Short Oil Alkyd White Enamel (Ashland P-216)	Soybean Oil resin in Butoxy ethanol/water solution (Arolon 363)	Industrial coatings	1.75 (14.6)		0.51 (4.26)	0.51 (4.26)
1Bs - SPRAY, Bake cured, solvent borne	1. Thermoset Acrylic White Enamel (Ashland P-36)	Selfcrosslink acrylic in ethoxy ethanol/xylene (Aroset 701XA3-50)	Quality coat, good adhesion	1.64 (13.7)		1.63 (13.6)	1.94 (16.2)
	2. Thermoset Acrylic Black Enamel (Ashland P-188)	Acrylic resin in Xylene crosslink/melamine (Aroset 4110X60)	High gloss automotive, industrial coatings	1.15 (9.60)		1.03 (8.60)	1.28 (10.7)
	3. Thermoset Acrylic White Enamel (Ashland P-232)	Acrylic resin in Xylene crosslink/melamine (Aroset 4110X60)	High gloss automotive, industrial coatings	1.58 (13.2)		1.06 (8.80)	1.06 (8.80)
	4. Short Oil Alkyd White Primer (Ashland P-63)	32% Tall Oil, 40% Phth. Anh. in Xylene (Aroplaz 1453X50)	Light color industrial finishes	1.67 (13.9)		1.22 (10.2)	1.51 (12.6)
	5. Non-oxidizing Alkyd White Enamel (Ashland P-122a)	35% Coconut Oil, 41% Phth. Anh. in Xylene (Aroplaz 2580X60)	Ultradurable exterior & automotive	1.66 (13.8)		0.90 (7.50)	1.03 (8.60)

(continued)

TABLE 4. (continued)

PAINT CLASS	PAINT DESCRIPTION (FORMULATION)	COMPOSITION OF BINDER	SUGGESTED USE	NV kg/lit (lb/gal)	kg OV/lit NV (lb OV/gal NV)	
					buy	use
1Bs - (continued)	6. Non-oxidizing Alkyd Yellow, Gray, Green (Ashland R-322)	47% Castor Oil, 37% Phth. Anh. in Xylene (Aroplaz 2477X65)	Semi-dry Alkyd lacquer & baked enamel	2.35 (19.6)	2.65 (22.1)	7.27 (60.6)
1Bw - SPRAY, Bake cured, water borne	1. Modified Melinize Gray Surfacer (Ashland Q-509)	Linsed/Castor Oil in Butoxy Ethanol water solution (Arolon 324)	Sandable primer	2.08 (17.3)	0.67 (5.60)	0.67 (5.60)
	2. Medium Short Alkyd Orange Enamel (Ashland P-225)	Safflower Oil Alkyd in water/t. but./butoxyl ethanol water solution (Arolon 376)	Exterior, durable, bake or air dry	1.92 (16.0)	0.84 (7.00)	0.84 (7.00)
	3. Medium Short Alkyd Red Primer (Ashland Q-514)	Safflower Oil Alkyd in water/t. but./butoxyl ethanol water solution (Arolon 376)	Exterior, durable, bake or air dry	2.35 (19.6)	0.76 (6.30)	0.76 (6.30)
	4. Medium Short Alkyd Green Enamel (Ashland P-223c)	Safflower Oil Alkyd in water/t. but./butoxyl ethanol water	Exterior, durable, bake or air dry	1.54 (12.8)	0.84 (7.00)	0.84 (7.00)
2As - DIP, FLOW, CURTAIN, Air drying, solvent borne	1. Medium & Short Alkyd/Modified Rosin Gray Enamel (Ashland P-134)	51% Soybean, 30% Phth. Anh. (Aroplaz 7307N50)	Fast drying, general use, flexible, hard, tough	1.51 (12.6)	1.36 (11.3)	1.96 (16.3)
	2. Medium & Short Modified Rosin Black Enamel (Ashland P-134)	35% Soybean, 37% Phth. Anh. (Aroplaz 7424X50) Phenol-Rosin (Arochem 335) 51% Soybean, 30% Phth. Anh. (Aroplaz 7307N50) 35% Soybean, 37% Phth. Anh. (Aroplaz 7424X50)	Fast drying, general use, flexible, hard, tough	1.10 (9.20)	1.65 (12.1)	2.09 (17.4)
2Aw - DIP, FLOW, CURTAIN, Air drying, water borne	1. Short, Modified Alkyd Orange Enamel (Ashland P-215a)	Phenol-Rosin (Arochem 335)	Fast drying, good adhesion & toughness	1.49 (12.4)	0.11 (0.90)	0.11 (0.90)
	2. Short, Modified Alkyd White Enamel (Ashland P-238)	Safflower Oil Rosin - water dispersion type (Arolon 585)	Fast drying, good adhesion & toughness	1.69 (14.1)	0.12 (1.00)	0.12 (1.00)
2Bs - DIP, FLOW, CURTAIN, Bake cured, solvent borne	1. Short Alkyd Yellow Enamel (Ashland P-140)	35% Tall Oil, 38% Phth. in Xylene/Aliphatics (Aroplaz 7435XN50)	Toys, etc. Excellent for electrostatic spray	1.27 (10.6)	1.73 (14.4)	2.09 (17.4)

(continued)

TABLE 4. (continued)

PAINT CLASS	PAINT DESCRIPTION (FORMULATION)	COMPOSITION OF BINDER	SUGGESTED USE	NV kg/lit (lb/gal)	kg OV/lit NV (lb OV/gal NV)	
					buy	use
2Bs - (continued)	2. Oil Free Alkyd	Polyester in aromatic solvents (Aroplaz 6025R70)	Industrial high flexi- bility	1.20 (10.0)	1.16 (9.70)	1.16 (9.70)
2Bw - DIP, FLOW, CURTAIN, Bake cured, water borne	1. Short Oil Alkyd Red Enamel (Ashland P-243)	Safflower Oil Resin in water dispersion (Arolon 585)	High gloss, high solids, industrial use	1.32 (11.0)	0.48 (4.00)	0.48 (4.00)
	2. Short Oil Alkyd White Enamel (Ashland P-233)	Safflower Oil Resin in water dispersion (Arolon 585)	High gloss, high solids, industrial use	2.04 (17.0)	0.28 (2.30)	0.28 (2.30)
	3. Short Oil Alkyd Black Enamel (Ashland P227)	Safflower Oil Resin in water dispersion (Arolon 585)	High gloss, high solids, industrial use	1.46 (12.2)	0.29 (2.40)	0.29 (2.40)
	4. Modified Oil Maleinized Black Primer (Ashland Q-510)	Linseed/Castor Oil Resin in eth- oxy ethanol glycol butyl (Arolon 324)	Rust inhibitive	2.17 (18.1)	0.64 (5.30)	0.64 (5.30)
	5. Medium Short Alkyd Orange Primer (Ashland P-234)	Safflower Oil Resin in Butoxy ethanol/t. butanol water solu- tion (Arolon 377)	High gloss, hard flexible mar-resistand	1.52 (12.7)	1.01 (8.40)	1.01 (8.40)
	6. Modified Alkyd Gray Primer (Ashland 8635P1154)	Maleinized Oil Resin in Butoxy ethanol/mineral spirits water solution (Arolon 507)	Tough resin, outstanding pigment suspension for automotive use	1.92 (16.0)	0.60 (5.00)	0.60 (5.00)
	7. Maleinized Oil Resin Black Primer (Ashland Q-519)	Linseed Oil Resin in water solu- tion (Arolon 525)	Corrosion resistant, economical	1.34 (11.2)	0.95 (7.90)	0.95 (7.90)
	8. Maleinized Oil Resin Black Primer (Ashland Q-515)	Linseed Oil Resin in water solu- tion (Arolon 525)	Automotive use	1.46 (12.2)	0.76 (6.30)	0.76 (6.30)
	1. Medium Oil Alkyd Red Shop Coat (Ashland Q-14)	52% High Soya, 34% Phth. Anh. in Min. Spirits (Aroplaz 1082M50)	Low viscosity TTR266d-IV, high color retention	1.60 (13.3)	1.10 (9.20)	1.10 (9.20)
3As - COIL & ROLL, Air or mild heat drying, solvent borne	2. Medium Oil Alkyd Flat White Enamel (Ashland H-305a)	52% High Soya, 34% Phth. Anh. in Min. Spirits (Aroplaz 1082M50)	Low viscosity TTR266d-IV, high color retention	2.06 (17.2)	1.16 (9.70)	1.69 (14.1)
	3. Short Oil Alkyd White Enamel (Ashland B-15)	38% Soyabean Oil, 43% Phth. Anh. in Xylene/Min. Spirits (Aroplaz 7310X50)	Very flexible, high weather durability	2.24 (18.7)	1.27 (10.6)	1.57 (13.1)
3Bs - COIL & ROLL, Bake cured, solvent borne	1. Oil Free Polyester White (Ashland P-87)	Non-oxidizing Alkyd in Arom./ methyl-heptyl ketone (Aroplaz 6022R65)	Exterior coil coat	1.79 (14.9)	0.79 (6.60)	0.79 (6.60)

(continued)

TABLE 4. (continued)

PAINT CLASS	PAINT DESCRIPTION (FORMULATION)	COMPOSITION OF BINDER	SUGGESTED USE	NV kg/lit (lb/gal)	kg OV/lit NV (lb OV/gal NV)	
					buy	use
3Bs - (continued)	2. Silicone modifier Polyester White Enamel (Ashland P-77)	70% Oil Free Alkyd, 30% Silicone in Aromatic/polyester/butanol (Aroplaz 1711A960)	Good durability, economical	1.82 (15.2)	0.70 (5.80)	0.70 (5.80)
	3. Oil Free Polyester White Gloss Enamel (Ashland P-84)	85% Oil Free Alkyd, 15% Silicone in Arom./but. ac. (Aroplaz 6025R70)	Good exterior durability, economical	1.84 (15.3)	0.66 (5.50)	0.66 (5.50)
	4. Oil Free Polyester White Gloss Enamel (Ashland P-88)	Oil Free Alkyd in Aromatics (Aroplaz 6023R70)	Low temperature curing, interior & exterior	2.04 (17.0)	0.73 (6.10)	0.73 (6.10)
	5. Oil Free Polyester White Gloss Enamel (Ashland P-89)	Oil Free Alkyd in Aromatics (Aroplaz 6029S60)	Low temperature curing, interior & exterior	1.81 (15.1)	0.85 (7.10)	0.85 (7.10)
	6. Oil Free Polyester White Gloss Enamel (Ashland P-81)	Oil Free Alkyd in Aromatics (Aroplaz 6025R70)	High flexibility, color retention, adhesion	2.82 (23.5)	0.66 (5.50)	0.66 (5.50)
	1. Oil Free Polyester White Gloss Enamel (Ashland P-240)	Thermoset Alkyd in Butoxy ethanol water solution (Aroton 465)	Excellent color retention	1.74 (14.5)	0.32 (2.70)	0.32 (2.70)
3Bw - COIL & ROLL, Bake cured, water borne	2. Medium Short Alkyd Red Primer (Ashland Q-514)	Safflower Oil in butanol/butoxy ethanol water solution (Aroton 376)	High gloss, adhesion, corrosion resistant, flexible	2.35 (19.6)	0.76 (6.30)	0.76 (6.30)
	3. Medium Short Alkyd Green Enamel (Ashland P-223c)	Safflower Oil in butanol/butoxy ethanol water solution (Aroton 376)	High gloss, adhesion, corrosion resistant, flexible	1.55 (12.9)	0.84 (7.00)	0.84 (7.00)
	1. Short Oil Alkyd Red Primer (Ashland Q-602)	Soy Oil Resin in n-butanol water solution (Aroton 369)	Automotive & other high quality uses	1.44 (12.0)	0.31 (2.60)	0.31 (2.60)
	2. Short Oil Alkyd Flat Black (Ashland P-702)	Soy Oil Resin in n-butanol water solution (Aroton 369)	Automotive & other high quality uses	1.50 (12.5)	0.30 (2.80)	0.30 (2.80)
	3. Short Oil Alkyd Gloss Black (Ashland P-704)	Soy Oil Resin in n-butanol water solution (Aroton 369)	Automotive & other high quality uses	1.14 (9.50)	0.47 (3.90)	0.47 (3.90)
4Bw - ELECTROCOATS, Bake cured, water borne	4. Short Oil Alkyd Gray Primer (Ashland Q-601)	Soy Oil Resin in n-butanol water solution (Aroton 369)	Automotive & other high quality uses	1.43 (11.9)	0.31 (2.60)	0.31 (2.60)
	5. Short Oil Alkyd White Enamel (Ashland P-701)	Soy Oil Resin in n-butanol water solution (Aroton 369)	Automotive & other high quality uses	1.33 (11.1)	0.34 (2.80)	0.34 (2.80)

(continued)

TABLE 4. (continued)

PAINT CLASS	PAINT DESCRIPTION (FORMULATION)	COMPOSITION OF BINDER	SUGGESTED USE	NV kg/lit (lb/gal)		kg OV/lit NV (lb OV/gal NV)	
				NV		use	
5B - POWDERS, Bake cured	1. Epoxy, Conventional		Indoor or primer ¹	1.20-	0.012-	0.012-	0.012-
				1.30	0.018 ²	0.018 ²	0.018 ²
				(10.0-	(0.120-	(0.120-	(0.120-
				15.0)	0.150) ²	0.150) ²	0.150) ²
	2. Epoxy, low Temperature			1.16-	0.007-	0.007-	0.007
				1.79	0.010 ³	0.010 ³	0.010 ³
	3. Thermoset Polyester, Melamine cured		Outdoor metal ¹	(9.60-	(0.060-	(0.060-	(0.060-
				14.9)	0.080) ³	0.080) ³	0.080) ³
				1.16-	0.042-	0.042-	0.042-
				1.79	0.078 ²	0.078 ²	0.078 ²
				(9.60-	(0.350-	(0.350-	(0.350-
				14.9)	0.640) ²	0.640) ²	0.640) ²
	4. Thermoset Polyester, Urethane cured		Outdoor metal ¹	0.030-	0.030-	0.030-	0.030-
				0.048 ⁴	0.048 ⁴	0.048 ⁴	0.048 ⁴
				(0.250-	(0.250-	(0.250-	(0.250-
				0.400) ⁴	0.400) ⁴	0.400) ⁴	0.400) ⁴
				0.048-	0.048-	0.048-	0.048-
				0.060	0.060 ³	0.060 ³	0.060 ³
	5. Thermoplastic Polyester		Furniture, fencing ⁵	(9.60-	(0.400-	(0.400-	(0.400-
				14.9)	0.500) ³	0.500) ³	0.500) ³
				0.054-	0.054-	0.054-	0.054-
				0.070 ⁵	0.070 ⁵	0.070 ⁵	0.070 ⁵
				(0.450-	(0.450-	(0.450-	(0.450-
				0.580) ⁵	0.580) ⁵	0.580) ⁵	0.580) ⁵
	6. Thermoset Acrylic		Outdoor metal & equipment ¹	1.15-	0.001-	0.001-	0.001-
				1.31	0.004 ⁶	0.004 ⁶	0.004 ⁶
				(9.60-	(0.010-	(0.010-	(0.010-
				10.9)	0.030) ⁶	0.030) ⁶	0.030) ⁶
				1.20-	0.030-	0.030-	0.030-
				1.52	0.042 ²	0.042 ²	0.042 ²
				(10.0-	(0.250-	(0.250-	(0.250-
				12.7)	0.350) ²	0.350) ²	0.350) ²
				0.098-	0.098-	0.098-	0.098-
				0.124 ²	0.124 ²	0.124 ²	0.124 ²
				(0.820-	(0.820-	(0.820-	(0.820-
				1.030) ²	1.030) ²	1.030) ²	1.030) ²

(continued)

TABLE 4. (continued)

PAINT CLASS	PAINT DESCRIPTION (FORMULATION)	COMPOSITION OF BINDER	SUGGESTED USE	NV lb/gal (lb/gal)		kg OV/lit NV (lb OV/gal NV)	
				buy		use	
5B - (continued)	7. Vinyl		Outdoor furniture, bicycles ¹ Fencing, wires, under- ground uses ⁷	1.20- 1.68 (10.0- 14.0)		0.005- 0.026 ⁷ (0.050- 0.220) ⁷	0.005- 0.026 ⁷ (0.050- 0.220) ⁷
	8. Cellulose Acetate Butyrate		Furniture ¹	1.14- 1.32 (9.50- 11.0)		0.060- 0.096 ⁴ (0.500- 0.800) ⁴	0.060- 0.096 ⁴ (0.500- 0.800) ⁴
6eb - RADIATION, Electron beam cured	1. Polyester, US Pat. 3,437,514 (Ford Motor Co.)	56% Styrene, 3% Maleic Anh.	Wood & metal	0.91+ (7.60)+		0.048+ (0.400)+	0.048+ (0.400)+
	2. Clear Acrylic, US Pat. 3,437,514 (Ford Motor Co.)	97% Acrylates	Wood & metal	0.91+ (7.60)+		0.048+ (0.400)+	0.048+ (0.400)+
	3. White Acrylic, US Pat. 3,437,513 (Ford Motor Co.)	90% Acrylates, 8% Styrene	Wood & metal	0.91+ (7.60)+		0.048+ (0.400)+	0.048+ (0.400)+
	4. White Silicone Polyester, US Pat. 3,437,513 (Ford Motor Co.)	30% Polyester, 30% Styrene, 10% Acrylic Siloxane, 30% Methyl Metacrylate	Wood & metal	0.91+ (7.60)+		0.048+ (0.400)+	0.048+ (0.400)+
6uv - RADIATION, Ultra- violet ray cured	1. Polyester		Printed decorations	Unk (Unk)		0.024 ⁸ (0.200) ⁸	0.060 ⁸ (0.500) ⁸
	2. Acrylic		Clear overcoats	Unk (Unk)		0.024 ⁸ (0.200) ⁸	0.060 ⁸ (0.500) ⁸
	3. Poly-thioether (W.R. Grace & Co.)		Elevated temperature coats, magnetic wire	Unk (Unk)		Unk ⁹ (Unk) ⁹	Unk ⁹ (Unk) ⁹
7As - HIGH SOLIDS, Air- drying, solvent borne	1. Acrylic White & Haas QR 568	59% Acrylic oligomer, 41% Des- modur N in ethoxy ethanol acetate monomer	Large equipment, heat sensitive items, shop refinishing	1.58 (13.2)		0.68 (5.70)	0.68 (5.70)

(continued)

TABLE 4. (continued)

PAINT CLASS	PAINT DESCRIPTION (FORMULATION)	COMPOSITION OF BINDER	SUGGESTED USE	NV kg/lit (lb/gal)		kg OV/lit NV (lb OV/gal NV)	
						buy	use
7Bs - HIGH SOLIDS, Bake cured, solvent borne	1. Acryloid OL 42 White Enamel (Rohm & Haas)	Hydroxyl acrylic oligomer in ethoxy ethanol crosslink with melamine	Indoor & outdoor furni- ture, air conditioners, etc.	1.72 (14.3)		0.50 (4.20)	0.50 (4.20)
	2. Acrylic White Enamel (Rohm & Haas)	40% Carboxyl acrylic oligomer, 60% Epoxy in crosslink with Methyl-amy-1-ketone/toluene 75/25 wt%	Low energy porcelain replacements	1.69 (14.1)		0.59 (4.90)	0.59 (4.90)
8Bw - LOW SOLVENT, Bake cured, water borne	1. Acrylic White Enamel (Ashland EF-11)	Acrylic emulsion in water (Aroclon X-801)	General industrial or outdoor over primer	1.19 (9.90)		0.18 (1.50)	0.18 (1.50)
9Bw - POWDER SLURRY, Bake cured, water borne	1. Acrylic White Enamel	Acrylic powder in water	General industrial	1.36 (11.3)		0.018# (0.150)#	0.018# (0.150)#

1 G. E. Cole, Jr.; SNE paper, FC 74-560, and direct communication.
2 R. D. Hardy & T. W. Seitz; SNE paper, FC 74-589.

3 O. J. Stvan, Sherwin-Williams Co.; Newer Formulations, and direct communication.

4 T. W. Seitz, Sherwin-Williams Co.; Newer Formulations, and direct communication.

5 P. R. Gribble, SEM-Glidden-Durkee; direct communication.

6 R. A. Johnston, Eastman Chemical Products, Inc.; Newer Formulations, and direct communication.

7 J. W. Hagen, Union Carbide Corporation; direct communication.

8 S. H. Schroeter, General Electric Company; "The Ultraviolet Cure of Solventless Resins", Non-polluting Coatings & Coating Processes; Gardon

& Prane, Editors; Plenum Press, New York, N. Y. 1973.

9 A. D. Ketley, W. R. Grace & Company; SNE paper, FC 73-331.

* Data given for Paint Class 5B only include liberated organic coreactants.

+ Data given are estimates.

Data given include liberated organic coreactants.

TABLE 5. RANGE OF OV AND NV WITHIN PAINT CLASSES SURVEYED

PAINT CLASS	CODE	CURE	CARRIER	kg OV/lit NV	lb OV/gal NV	kg OV/lit (OV+NV)	lb OV/gal (OV+NV)
SPRAY	1As	Air dry	Solvent	1.09 - 4.45	9.1 - 37.1	0.54 - 0.69	4.43 - 5.70
	1Aw	Air dry	Water	0.52	4.3	0.34	2.76
	1Bs	Bake	Solvent	0.90 - 1.27	7.5 - 60.6	0.47 - 0.78	3.91 - 6.41
	1Bw	Bake	Water	0.67 - 0.84	5.6 - 7.0	0.40 - 0.45	3.26 - 3.68
DIP, FLOW, CURTAIN	2As	Air dry	Solvent	1.36 - 2.09	11.3 - 17.4	0.60 - 0.62	4.98 - 5.07
	2Aw	Air dry	Water	0.11 - 0.12	0.9 - 1.0	0.10 - 0.11	0.80 - 0.88
	2Bs	Bake	Solvent	1.16 - 2.09	9.7 - 17.4	0.50 - 0.62	4.12 - 5.07
	2Bw	Bake	Water	0.28 - 1.01	2.3 - 8.4	0.20 - 0.42	1.65 - 3.47
COIL & ROLL	3As	Air dry	Solvent	1.10 - 1.69	9.2 - 14.1	0.44 - 0.51	3.61 - 4.17
	3Bs	Bake	Solvent	0.66 - 0.85	5.5 - 7.1	0.38 - 0.44	3.17 - 3.64
	3Bw	Bake	Water	0.32 - 0.84	2.7 - 7.0	0.24 - 0.44	1.99 - 3.62
	4Bw	Bake	Water	0.30 - 0.47	2.6 - 3.9	0.23 - 0.30	1.87 - 2.50
POWDERS	5B	Bake	None	0.005 - 0.124	0.005 - 1.03	0.01 - 0.11	0.05 - 0.87
RADIATION	6eb	Elec. Beam	None	0.05	0.4	0.05	0.38
	6uv	U'violet Ray	None	0.024 - 0.06	0.2 - 0.5	0.02 - 0.06	0.19 - 0.47
HIGH SOLIDS	7As	Air dry	Solvent	0.68	5.7	0.39	3.24
	7Bs	Bake	Water	0.50 - 0.59	4.2 - 4.9	0.33 - 0.36	2.69 - 2.97
LOW SOLVENT	8Bw	Bake	Water	0.18	1.5	0.15	1.25
POWDER SLURRY	9Bw	Bake	Water	0.018	0.15	0.016	0.14

GLOSSARY

- as bought: A composition as produced by the manufacturer and delivered to the user.
- as used: A composition as used by the consumer. Some compositions may be used "as bought" while others may have additional components added to achieve the desired characteristics for use.
- calculation: The mathematical operation used to arrive at a numerical answer.
- constant (K factor): A constant factor developed for use in mathematical calculations designed to provide specific results.
- coreactant: An organic volatile substance liberated from a nonvolatile solid as a result of chemical reaction.
- curing method: The method by which the organic volatiles are evaporated from the paint liquid to leave a solid nonvolatile film.
- density: the specific weight/volume of a substance.
- determined waste: The actual waste generated as determined after the fact.
- electrostatic field: A field of static electricity that imparts a charge to particles which pass through it.
- filmformer: A nonvolatile substance consisting of particles that can be formed into a film on a solid surface.
- hot melt: A nonvolatile solid substance that will melt into a liquid state at a relatively low temperature.
- merchandise: A manufactured product made from a solid material.
- nonvolatile: A nonevaporative solid substance.
- organic volatile: A substance essentially composed of carbon, hydrogen, and oxygen which will evaporate into the atmosphere.
- paint composition: A formulation of materials designed for used in applying a nonvolatile film coating to the surface of a solid material.
- painting operation: An operation in which a nonvolatile solid film coating is applied to the surface of a solid material.

- painting process: The method used to transfer a paint composition from a container to the surface of a solid material.
- predicted waste: The waste estimated to be produced by a planned painting operation using a specific painting process and curing method.
- primer coat: An initial paint coating applied to the surface of the merchandise to prepare the surface for a final "top" coating.
- transfer efficiency: A factor, usually expressed as a percentage, to represent the amount of nonvolatile solids in the paint composition used that will actually become the final film coating on the merchandise.
- top coat: The final film coating on the finished merchandise.
- viscosity: The specific gravity of a paint composition.
- volume percent: The relationship of components in a paint composition expressed in units of volume.
- waste load: The pollutorial waste generated during a painting operation, usually expressed in units of weight.
- weight percent: The relationship of components in a paint composition expressed in units of weight.